Metal Progress

Table of Contents for March, 1946

Cover: "Reconversion", by Howard King

Atomic Age

Russia Plans for the Future — 562
— And Acquires Some Information on Nucleonics 563

Technical Articles

Production Line Heat Treatment of Stainless Bar Stock, by *J. F. Sullivan* 523
Some Notes on the National Metal Congress and Exposition, by *Our Special Observer* 526
Metallurgical Aspects of High Quality Pressure Welded Joints for Landing Gear — Part II — Tests, Set-Up, and Inspection, by *Leslie Fine, Charles H. Maak* and *Anthony R. Ozanich* 530
Manufacture of Ferrous Metal Powder Parts — Pictorial Story Photographed by *F. M. Demarest*, Text by *Paul Schwarzkopf* and *Claus G. Goetzel* 539
Industrial Significance of the Basic Characteristics of Magnesium, by *J. D. Hanawalt* 548
New Developments in the Study of Surface Chemistry, by *Earl A. Gulbransen* 553
Brittle Failure of Hogged-Out Fittings From 14S-T Billets, by *Given Brewer* and *Herman C. Ihsen* 566
The Heckled Band, by *D. Carb* 571

Bits and Pieces

First-Piece and Patrol Inspection, by *A. L. Atherton* 536
Accurate Hardness Surveys, by *J. A. Erickson* 537
Removing Carbide Tips From Tool Shanks, by *R. G. Maurer* 537
Electropolishing Without Rounding the Edges, by *John M. Kiefer* 537
Adhesive Tension Patches, by *E. R. Weaver* 538
Continuous Induction Hardening, by *E. E. Alexander* 538

Correspondence

Research on Metallic Surfaces Organized in France, by *Albert M. Portevin* 560
Fossil Tracks, by *Robert J. Johnson* 561
Alloy Steel or Alloy-Treated Steel? by *Howard F. Bartell* 561
Stress-Corrosion Cracking of 18-8, by *Russell Franks* 563
Safe Packing and Shipment of Ordnance Parts, by *David J. Mack* 565
Inferior Stainless Cutlery, by *Philip F. Atwood* 565

Departments

Data Sheet, Diagrams for Yield Ratio and P Value, by *Roger F. Mather* 552-B
Personals .. .. 576 e.s.
Manufacturers' Literature 616-A
Advertising Index 662

Abstracts of Important Articles

Graphitization in Steam Lines 588
From "Graphitization of Low Carbon and Low Carbon-Molybdenum Steels", by *H. J. Kerr* and *F. Eberle*, Welding Journal, Feb. 1945, p. 86s to 122s; Discussion, Welding Journal, June 1945, p. 350s to 359s.

German Corrosion Research 594
From Korrosion und Metallschutz, V. 20, No. 1, Jan. 1944, p. 63 to 76; V. 20, No. 2, Feb. 1944, p. 107 to 113.

Superheating Magnesium Alloys 598
From "Superheating in Magnesium-Base Alloys", by *F. A. Fox* and *E. Lardner*, Engineering, V. 159, June 1, 1945, p. 438 to 440; June 15, 1945, p. 478 to 480.

Friction Tests on Bearing Alloys 604
From "The Frictional Properties of Some White Metal Bearing Alloys: the Role of the Matrix and the Hard Particles", by *D. Tabor*, Journal of Applied Physics, V. 16, June 1945, p. 325 to 337.

Cracks in Thin Welded Plate 608
From "How Does Propagation of a Small Crack Take Place in Thin Plates?" by *L. E. Grinter*, Welding Journal, June 1945, p. 319s to 320s.

Hardness Testing Errors 610
From "Sources of Error in Diamond Pyramid Hardness Measurements on Hardened Steel", by *W. N. Hindley*, British Iron and Steel Institute, Advance Copy, Sept. 1945.

Grinding Aircraft Gears 654
From "Should Aircraft Engine Gears Be Ground?" by *E. A. Koether*, Grits and Grinds, V. 36, No. 8, August 1945, p. 1 to 5.

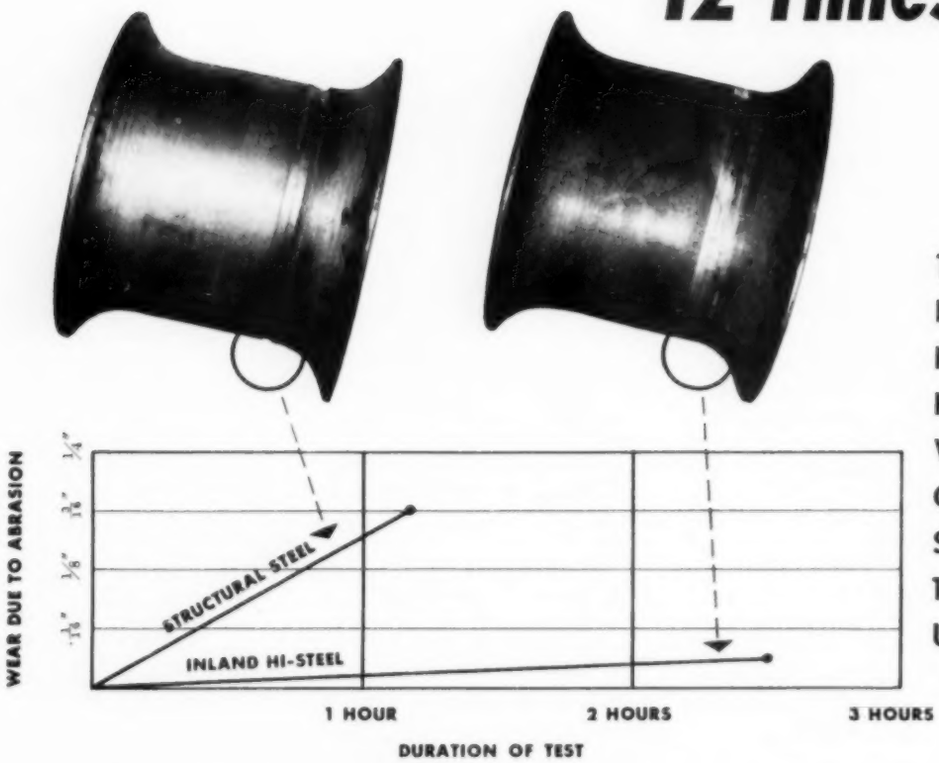
Carburizing Practice in Germany 656
From Korrosion und Metallschutz, V. 19, No. 12, Dec. 1943, p. 309; V. 19, No. 12, Dec. 1943, p. 320 to 322.

Microporosity 658
From "The Properties of Some Magnesium-Aluminum-Zinc Casting Alloys and the Incidence of Microporosity", by *F. A. Fox*, Journal of the Institute of Metals, V. 71, 1945, p. 415 to 439.

Corrosion of Magnesium Alloys 660
From "Further Observations on the Protective Influence of Manganese in the Corrosion of Aluminum-Containing Magnesium Alloys", by *F. A. Fox* and *C. J. Bushrod*, Journal of the Institute of Metals, V. 71, May 1945, p. 255 to 265.

Resists Abrasion . . .

12 Times Longer!



Tests Show That Inland HI-STEEL,* In the Precipitation Hardened Condition, Will Outwear Ordinary Structural Steel More Than 12 Times When Used For Winch Heads

*TRADEMARK—REG. U. S. PAT. OFF.

Recent tests were undertaken by American Hoist & Derrick Co., St. Paul, Minn., to determine the comparative wearing qualities of winch heads—made of Hi-Steel in the precipitation hardened condition and of ordinary structural steel. To simulate actual field operation as closely as possible, the steel cable around the winch was held under load and the winch revolved. Both winch heads were of identical size and shape. In the first test of 70 minutes with ordinary structural steel, and in the second of 150 minutes with Hi-Steel (as indicated by the graph above), Hi-Steel's exceptionally higher resistance to abrasion was clearly demonstrated.

Along with superior resistance to wear, Hi-Steel also offers you a high strength steel—permitting considerable weight reduction while maintaining the required structural strength—as well as great resistance to fatigue, impact, and atmospheric corrosion. Since Inland Hi-Steel can be furnished in most structural sections, plates, strip and sheets, and is economical to use, its applications are many and varied.

A partial list of products in which Hi-Steel is successfully used: Bins, Boats, Bolts, Booms, Bridges, Buckets, Busses, Chutes, Construction equipment, Conveyors, Cranes, Cyclone stacks, Locks, Floor Plates, Hoists, Hoppers, Material handling equipment, Mine equipment, Ore cars, Railway cars, Screens, Stacks, Structural framework, Tanks, Trailers, Trucks and Ventilators.

Write for the Inland Hi-Steel Engineering Bulletin No. 11. Inland Steel Company, 38 S. Dearborn St., Chicago 3, Ill. *Sales Offices:* Cincinnati, Detroit, Indianapolis, Kansas City, Milwaukee, New York, St. Louis, St. Paul. *Principal Products:* Bars, Structurals, Plates, Sheets, Strip, Tin Plate, Floor Plate, Piling, Reinforcing Bars, Rails, Track Accessories.

INLAND HI-STEEL

Treating Stainless Bars

Production Line Heat Treatment of Stainless Bar Stock

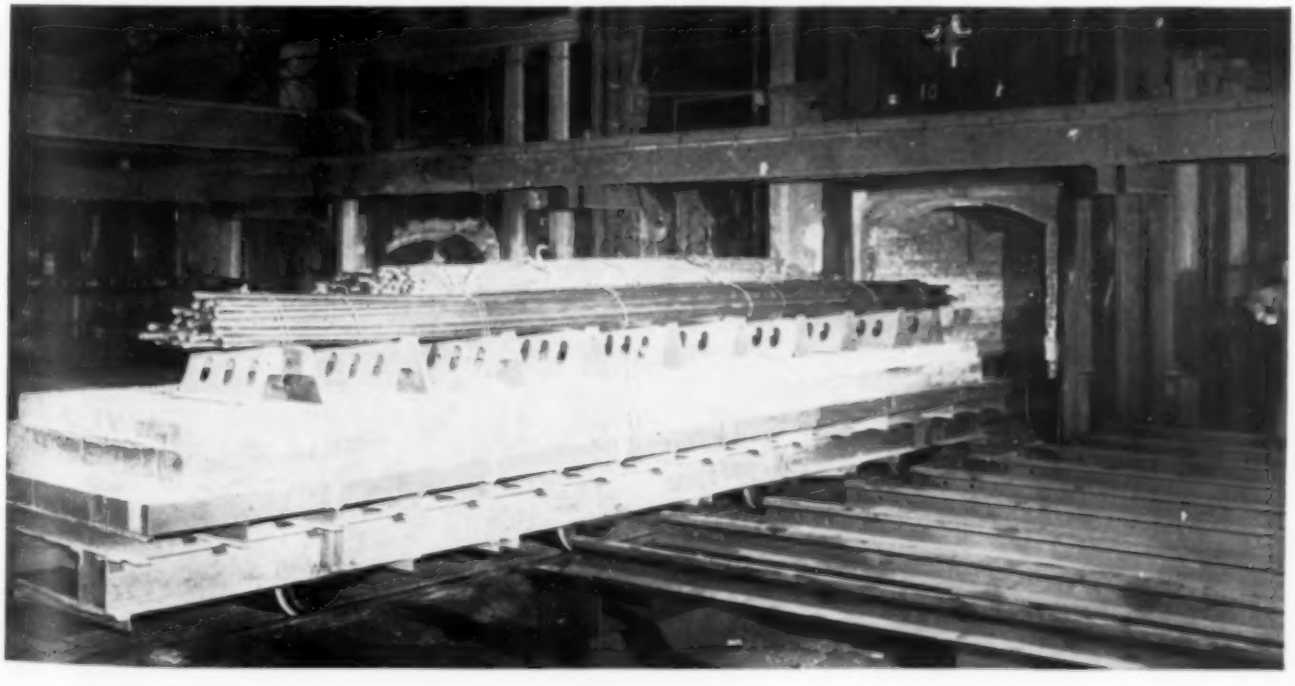
By J. F. Sullivan
Allegheny Ludlum Steel Corp., Watervliet, N. Y.

ECONOMIES that can be derived from heat treatment in the production of stainless bar stock are responsible for the development of a heat treating production line of high efficiency at the Watervliet plant of Allegheny Ludlum Steel Corp. It is probable that few users of stainless bar stock realize the amount of heat treatment it receives at the mill producing it and the precision that is attained in these large scale operations. The Editor of *Metal Progress* commented briefly on this in his "Critical Points" in last November's issue, and it is doubtless of enough importance to be elaborated.

With six oil and six electric furnaces (some of which are large enough to take stock 22 ft. long) in a relatively small and compact department as measured by space requirements and man power, an output of more than 3,000,000 lb. per month was maintained during the war. This included hardening, tempering, annealing and stress relieving operations to produce bar hardnesses ranging on customers' order from 140 to 321 Brinell.

Several features of the departmental layout make these accomplishments possible. First, the furnaces are in line, as shown in the general plan (Fig. 2) on the next page, so that a gantry crane traveling on a low track in front of all furnaces can rapidly load any of the furnace bottoms, and take hot charges from them to the water or oil quench tanks. Rapid transfer is facilitated by the

Fig. 1 — Bars as Long as 22 Ft. Can Be Put Into Some of the Heat Treating Furnaces. Pier castings of high heat resisting alloy, maintained with tops level, minimize distortion of hot bars, and permit fast placement and removal of the charge by the L-shaped fork on the gantry crane



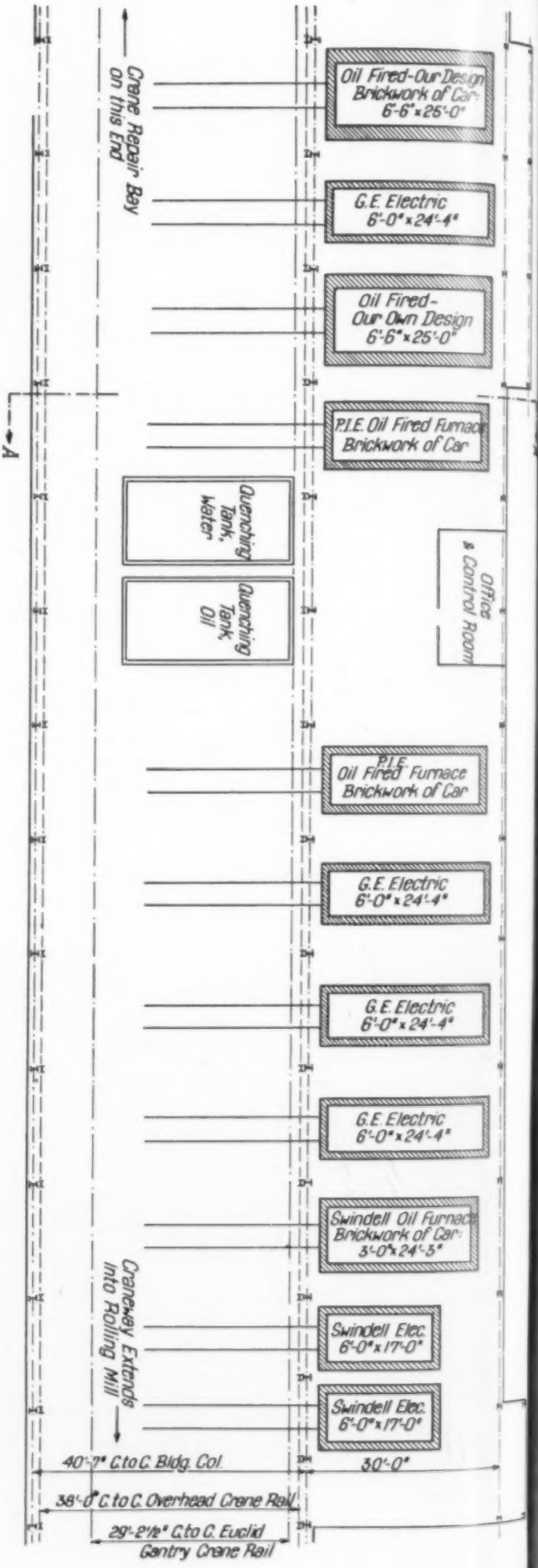
automatic positioning of furnace car-bottoms, so that the crane's L-shaped fork (of our own design) can pick up or lay charges on a series of pier castings. All furnace charges are laid out in advance on conveniently located racks in the line of travel of the gantry crane, thus saving time when the furnace cars are out in the open awaiting a new charge, conserving furnace heat, and reducing the total heating time of the charge. Car pier castings and tines of the crane fork are so spaced as to reduce sagging of the bars during treatment, or of the hot bars during transfer.

One important feature of economical and precise furnace operation is the centralized automatic temperature control in an office near the middle of the department. Recording instruments of potentiometer type control both oil and electric furnaces. These instruments are arranged with a program control so that the preferred heating cycle is automatically achieved. When the maximum temperature is reached, it is held automatically. Also the devices maintain manually-set cooling temperatures in the annealing furnaces. All furnaces have from two to four zones, controlled by independent pyrometers. Depending on furnace design these zones may be top and bottom, sides, or front, center and back.

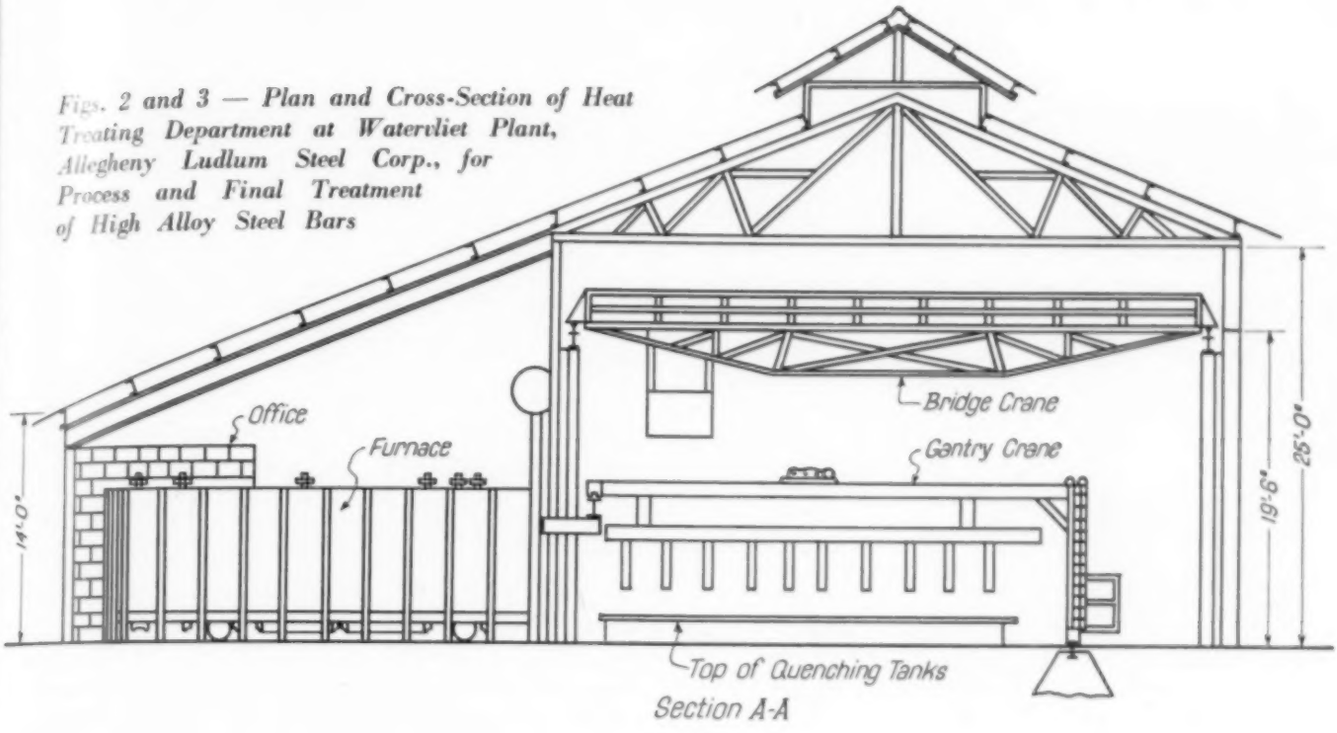
On the oil-fired furnaces the instruments control Hauck proportioning burners, operated by motors that open and close the air and oil orifices in response to pyrometer reactions. A group of burners are connected together mechanically by push rods so as to be operated simultaneously in a given zone. The ratio of oil-to-air in the burners is manually adjustable to produce the atmosphere desired for the type of material being heated in the furnace. Controls are of two types: *(a)* the two-position control for high and low heat output and *(b)* the modulating type, which permits much closer temperature regulation.

Heat input of the electric furnaces — which are used largely for stress relieving and tempering and are operated at temperatures between 1100 and 1400° F. — is closely controlled by pyrometers that operate switches and circuit breakers for closing and opening circuits leading to the resistors. One of these furnaces is equipped with a radiator through which cold air can be circulated when fairly fast cooling is desired. Four of the electric furnaces have a maximum heat input of 390 kw. and two smaller ones have an input of 310 kw.

After the steel is uniformly heated to specified temperature, the car bottom carrying the bars is run out into the front bay, and the load is rapidly transferred either to the 6000-gal. oil tank or the water quench tank of the same capacity. This is


Crane Repair Bay on this End
A
Oil Fired-Our Design Brickwork of Car 6'-6" x 25'-0"
G.E. Electric 6'-0" x 24'-4"
Oil Fired-Our Own Design 6'-6" x 25'-0"
P.I.E. Oil Fired Furnace Brickwork of Car
Quenching Tank, Water
Quenching Tank, Oil
Office & Control Room
P.I.E. Oil Fired Furnace Brickwork of Car
G.E. Electric 6'-0" x 24'-4"
G.E. Electric 6'-0" x 24'-4"
G.E. Electric 6'-0" x 24'-4"
Swindell Oil Furnace Brickwork of Car 3'-0" x 24'-5"
Swindell Elec. 6'-0" x 17'-0"
Swindell Elec. 6'-0" x 17'-0"
Craneway Extends into Rolling Mill
40'-7" C. to C. Bldg. Col.
30'-0"
38'-0" C. to C. Overhead Crane Rail
29'-2 1/2" C. to C. Euclid Gantry Crane Rail

Figs. 2 and 3 — Plan and Cross-Section of Heat Treating Department at Watervliet Plant, Allegheny Ludlum Steel Corp., for Process and Final Treatment of High Alloy Steel Bars



done by the gantry crane as previously outlined. The crane operator improves the uniformity of cooling in the tank by raising and lowering the submerged load. This, of course, makes the steel more uniform in hardness and grain structure.

The temperature of the quenching medium is automatically controlled by circulating the oil through a heat exchanger. Fire hazard from the oil tank is minimized by provision of ample pumps and pipe lines so oil can be drawn from the bottom of the quench tank and put into underground storage. (Foam blanket extinguisher equipment is also ready to operate.) This underground storage tank is used also when the oil tank must be drained for cleaning.

The bulk of the tonnage heat treated at this plant consists of austenitic 18-8 types of the A.I.S.I. 300 series, martensitic types 410, 414, 416, 420 and 440-C, nitralloy, and valve steels — both automotive and aircraft. Heat treatment of certain types of these materials to special physical properties on a production scale saves several operations in the fabrication of many parts because the steel needs no further heat treatment to meet the requirements of the fabricator and of the finished part. Thus, costs are avoided that would otherwise have to be added for extra heat treatment and cleaning operations of steel purchased in the annealed condition. This saving can be passed on to users of finished parts or products in a lower selling price. Another advantage of heat treated bars up to 22 ft. is that machining costs on automatic screw machines are lower because long bars give proportionately less waste per bar, and reduce off-time for reloading machines.

For such reasons as these our sales department finds that heat treated bars — long bars — in rounds, squares, hexagons, and some special shapes are being used by an increasing number of fabricators for parts of all sorts — even those that require little or no machine finishing operations.

Fig. 4 — Bars to Be Quenched Are Lowered Into the Tank on an L-Shaped Fork. Fork tines permit quick handling of bars from supports such as the loading rack shown alongside the quench tank, and are close enough together to prevent serious warpage of hot bars. Similar supports are on the car bottoms and in the bottom of quench tanks. Note, at extreme right, the glass-walled office and control room

Convention

Some Notes on the National Metal Congress and Exposition

By Our Special Observer

A CONFIRMED addict of the national gatherings of the American Society for Metals, such as your reporter, sees great similarity in the meetings, year after year, even though he must know, if he thinks about it, that their content — like his personal appearance — is changing continuously even if imperceptibly. So he idly turned back at random to the A.S.S.T. *Transactions* for 1923, and the document verifies his impression that the exhibits (in addition to outgrowing the capacity of the largest halls in America) have measured a rapid change in the metallurgical industry. Toolsteels were then presented by many manufacturers; now the emphasis is on engineering alloys, stainless and heat resisting. Batch furnaces, both gas and electric, now have prepared atmospheres and many automatic features for labor saving and tonnage production. *Then* we saw the American Car and Foundry's electric rivet heater; *now* there are induction devices for all sorts of treatment using currents up to mega-cycle frequencies. To optical instruments have been added others utilizing X-rays and super-sonic waves. Manual welding with oxy-acetylene flame and arc is an old story; electronic controls have invaded this field also and we see the fancifully-named "electronic bloodhound" for flame cutting to intricate shape, the control of resistance welders to a fraction of a cycle, and time programs for current dwell and repetition to temper or stress-relieve the spots as they are welded. And, of course, the whole light metal industry is now with us.

Next as to the type of papers then and now. Then (in 1923, to be specific) there were numerous papers on furnaces and fuels, toolsteels and toolroom troubles, a session on carburization, another discussing automobile sheet steel — all eminently practical, and nostalgic to those of more "practical" leanings who perhaps were starry-eyed the other day after listening to the Campbell Memorial Lecture. In this lecture Gensamer said at the outset that the tensile test was the most useful of all tests, and the hard-bitten metallurgist immediately said to himself, "It certainly means little in the testing of casehardened pieces or other structures of high hardness, or even of soft sheet steel". Gensamer's lecture, which will appear in the next volume of *Transactions* (and soon in summary in *Metal Progress*, I am assured by the Editor) should certainly be regarded in a different light. The real meaning of his opening remark was that there is much information available from the tensile test that is now unused and which, when properly interpreted, will lead the investigator to a new viewpoint on how to improve the inherent properties of metal. Gensamer's analysis inevitably introduced mathematical statements and some things that appeared speculative, yet — if they are correct — they will prove to be fundamentals to the researchers of the next generation.

It is well for the ⊕ to be out in advance of the procession. It was, even in 1923, for I find in that same old convention a paper by Zay Jeffries and R. S. Archer on "The Hardening of Steel". It is safe to assert that when these eminent authors presented evidence gained by the X-ray spectrometer that martensite contained multitudes of particles about 150 atom diameters in size (0.000,0015 in.), the hard-bitten metallurgist of *that* day dismissed the matter as of no immediate importance. Yet if the award of medals and honors means anything, such work of these two men which led up to their slip interference theory of hardening has been of incalculable benefit to modern developments in the art of alloying. The problem of hardening of steel — or "transformation of austenite", the metallurgist of scientific turn of mind would say — is also by no means settled, as anyone could learn even if he were from a far country and attended the 1946 sessions.

Less Than One-Fifth of the Show Was Contained in the Main Auditorium

The first round table discussion, on the decomposition of austenite*, was indeed of such a nature as to cause some uneasiness among students of hardenability. The panel of experts was unable to agree even on the effect of carbon content on the rate of pearlite transformation. Measurements of a steel during continuous cooling have indicated that increases in carbon content decrease the critical cooling velocity and hence increase the hardenability. These data were in accord with those Grossmann used in establishing his well-known hardenability system, and check age-old experience that high carbon steels are easy to harden. However, some other data were quoted that indicate that — at least when austenite transforms isothermally in alloy steels — increases in carbon content *decrease* the incubation time necessary for the first pearlite to form, and hence *decrease* the hardenability insofar as hardenability (a complex property) is related to rates of pearlite growth — *pearlite*, rather than martensite.

An excellent paper on the effect of carbon content on the transformation characteristics of chromium steels, presented at one of the technical sessions by Troiano and Lyman, includes data supporting the latter conclusion. These authors also quote some German information that is in full agreement. Some theoretical analyses presented by Zener and by Brandt in the round table discussion on the rate of growth of pearlite once it starts to form are in disagreement as to the effect of carbon content. If the excellent data of Troiano and Lyman do actually apply to conditions during the continuous cooling of less highly alloyed steels, one of the basic hypotheses of the Grossmann hardenability system cannot be correct, and the conclusion must be that an increase of carbon content cannot actually increase the "hardenabil-

*It is planned to publish the complete transcript of the three round table discussions in future issues of *Metal Progress*.

ity". This confusing state of affairs illustrates the lack of good data as to the effect of alloying elements, singly and alone, and of carbon content of and by itself, on the isothermal transformation of austenite and on continuous cooling transformation. It would seem that further analysis of the general problem of steel's hardenability cannot proceed until these conflicts are harmonized.

In recent years the metallurgical underground has carried many rumors concerning the nature of the boron effect. It had been assumed on the basis of these rumors that it was connected with the amount of combined nitrogen in the steel. Coming out in the open, a most interesting study was reported to the ⊜ convention by Grange and Garvey of the influence of boron on the transformation characteristics of several steels. They concluded that its effect was rather unpredictable. In the main, they confirmed that small amounts would decrease the rate of transformation. They also found a technique of delineating the precipitate associated with the boron effect by metallographic means. They demonstrated that, by high temperature treatments, the effect of boron on hardenability could be permanently removed, yet chemical analysis on the amount of insoluble boron before and after showed no change. (It had been suggested that the acid-soluble nitrides correspond with steel-soluble nitrides.)

It will now be interesting to hear the effects of this experiment on the conclusions of the metallurgists of the underground.

It is most interesting to note that the early concepts of Jeffries and Archer and the early studies of Jeffries on tungsten wire are now being applied to "super-alloys" for turbo-chargers and jet engines. Many years ago Zay Jeffries demonstrated that the resistance to creep at elevated temperatures increased with increasing grain size, and he attributed this increase to the low resistance of grain boundary material to plastic flow at elevated temperatures. Members of the round table discussion on Tuesday evening laid emphasis upon the production of castings of large grain size for high temperature application. It was intimated that vacuum melting might certainly be warranted if it would remove impurities that inhibit grain growth. Research on the subject of the relative importance of the resistance of grain boundary material and the grains themselves to plastic deformation is about to get underway at the new Institute for the Study of Metals at the University of Chicago, if Clarence Zener, one of the members of that Institute, can have his way. Certainly, the quantitative knowledge of the fundamentals of high temperature behavior based on the early work of Jeffries would be most helpful in this field of high temperature alloys for severe services.

There was considerable discussion at the round table on high temperature alloys of the mechanism of the precipitation that occurred at elevated temperatures in some of the new and complex alloys. This precipitation often increased the creep resistance and often increased the resistance to rupture. The discussion by the experts on the panel seemed to indicate that this precipitation was quite unlike the precipitation that occurs in the age hardening of duralumin. One of the audience asked specifically if this was the case. Since there is frequently no increase in hardness while the specimen is under load it might seem that the two processes were in fact quite different. However, recrystallization occurring at the elevated temperature as well as other more complex phase changes could easily counteract the hardening effect of the precipitate. Certainly much more work is warranted in the high temperature field.

Much of the new equipment and machinery exhibited at the Metals Exposition illustrates the trend toward the use of light alloys for stressed parts. Desire for higher speeds and light weight would seem to require the use of light alloys in transportation equipment. However, several off-the-record discussions heard by this correspondent seem to indicate a backwardness on the part of both manufacturers and users of alloy constructional *steels* to employ materials of the higher yield strengths. Whereas many of the light alloys such as duralumin have long been used at their maximum strength wherein the maximum advantage of precipitation hardening is obtained, steels, on the other hand, are frequently used at yield strengths as low as 35,000 psi. and no higher than 70,000, particularly in the construction of transportation equipment. The use of the higher strength steels has become commonplace for ordnance matériel during the war, and many manufacturers have learned how to fabricate steels of good ductility and toughness at yield strengths higher than 100,000 psi. It would seem to be easier to specify a newer material for any of these parts than to raise the requirements for the old standby, steel, yet when steel at these higher strength levels is compared to the light alloys, not only is the cost favorable, but also the strength-weight ratio. Special means are often necessary in the thinner steel members to prevent buckling under load. Conversations overheard in and about the Statler, the headquarters hotel, would indicate that in some of the newer railroad cars steels are

being used at strengths as high as 70,000 psi., whereas some metallurgists think that this strength could be doubled.

Bearing on the same problem, Maxwell Gensamer, in his Campbell Memorial Lecture when discussing the important problem of fracture, introduced a new concept to many in the audience in emphasizing that the complex stress system at the base of a notch (that is so deleterious to steel ductility) may not be directly the cause of low temperature brittleness of some steels; the gradient in strain beneath the notch may be of a much greater significance. Furthermore, the variation of this gradient may be responsible for the size effect so often discussed in connection with notched bar impact tests. His lecture also highlighted the growing understanding and acceptance of the concept of flow and fracture-stress curves. The complex ideas of the early German workers in this field are now being assorted and assimilated —particularly due to the efforts of Dr. Gensamer. Now that the concepts are becoming more clearly defined, the amount of research in this field should increase by leaps and bounds. Corridor discussion abounded of the important work being performed by the Russians on flow and fracture.

In presenting a paper on temper brittleness, Captain Hollomon of Watertown Arsenal laboratory pointed out how little attention this problem had received between the two world wars. Temper brittleness (originally found in Krupp armor) becomes particularly important whenever steel has to have extremely good toughness at relatively high hardness levels. For most engineering parts, the requirements are not as stringent as for guns, armor and projectiles. As a consequence, most of the research on the problem has been done either by governmental laboratories of the various nations or by manufacturers of ordnance steel. However, Hollomon pointed out that temper brittleness may be present in steels used for commercial parts and not be recognized as such. Those S.A.E. and N.E. steels containing little or no molybdenum are very susceptible to temper brittleness if they contain moderate amounts of other alloying elements. Thus, the problem is important to the users of alloy and constructional steels. In this same paper, a new etching reagent developed at Watertown Arsenal was mentioned, supposed to delineate between temper brittleness and non-temper brittle steels by means of a difference in grain boundary attack.

Victor Paschkis, of Columbia University, calculated the cooling rates in steel balls and rings by an electrical analog method. If all the variables of transient heat flow are included, direct methods of calculation become extremely complex. If, as has been assumed by others working in this field, the "H" value (severity of quench) is constant, the calculations are somewhat simplified. By Paschkis's electrical analog method, the variation of "H" value in the three stages of cooling may be introduced into the problem. Since the quenching of steel involves the three different stages of cooling, this much more accurate method of calculation should not only give better results but should stimulate interest in the fundamental study of the various stages of quenching. Certainly, more accurate methods of translating one size of steel part to another when quenched in various media would be of extreme interest.

Many people at the metal show seemed to be more interested in hiring metallurgists than in buying metal products. The dearth of well-trained physical and process metallurgists was proven by the many discussions about personnel problems. The policy of the Government that prevented the advanced training of scientific and engineering people during four years of war is now bearing its sour fruit. Important problems in the metallurgy of high temperature alloys, the transformations that occur in steel, the metallurgy of materials for atomic energy, and in the science of metals will all suffer. Schools already beginning to feel the effects of the tremendous influx of veterans taking advantage of the "G.I. Bill of Rights" require more instructors than seem to be available. Almost all of the young metallurgists who had good experience during the war have had many offers of excellent positions in their own field. A rapid expansion and acceleration of the training in physical metallurgy seems to be the only way to satisfy the growing demand. Yet for this expansion, academic personnel are not available. Before the required attention can be given to *better* training, metallurgists may have to be produced almost on a mass production basis!

Before signing off this fragmentary report of a most successful occasion, your reporter is tempted to suggest the inclusion of an electronic regulator for those electronic devices known as loud speakers. He would suggest that the corner posts of all those booths that contain public address systems, talkies, and moving machinery should conceal a decibel meter so connected that when the noise level exceeds the neighborly or endurance limit the electrical current would automatically be switched off and the offending equipment stilled. · Impartial, ever-watchful!

Pressure Welds

Metallurgical Aspects of High Quality Pressure Welded Joints for Landing Gear — Part II — Tests, Set-Up and Inspection

By Leslie Fine, Charles H. Maak and Anthony R. Ozanich
Metallurgical Laboratory, Menasco Mfg. Co., Burbank, Calif.

AN ARTICLE in last month's *Metal Progress* described the "Uniweld" machine used by Menasco Mfg. Co. to make high quality pressure welds in low alloy, medium carbon steel tubing and forgings. A prime cause of sub-standard joints was shown to be the presence of oxygenated metal along the weld plane, and that article described methods of proving its presence, and also showed that joints entirely free from such deleterious material could be made with modern production equipment. In this article we will now pass on to a discussion of methods for physical testing of pressure butt-welds in aircraft tubing.

In aircraft landing gear design, a prime consideration is a high strength-to-weight ratio. Steels generally used for the highly stressed members are the S.A.E. 4100 and 4300 series or equivalent NE steel substitutes possessing good ductility when heat treated to the 180,000 to 200,000-psi. tensile range. The principal stresses involved are bending, axial tension, axial compression, and torsion.

The test adopted by Menasco Mfg. Co. for determining the quality of pressure welds for aircraft landing gear is a static bend test on heat treated sections after the weld upsets have been removed entirely or to within 0.015 in. of the wall. Bend testing simulates one of the important stresses applied on a gear when the aircraft lands. Bend testing has also been demonstrated to be a more severe test than tension tests on coupons cut from the weld.

Tests on such steels in the as-welded state will not produce a reliable index of the quality of the weld because the weld is then harder than the adjacent metal. This allows the test specimen to fail at a value below that required to cause failure in the metal in the weld plane area. This is illustrated in Fig. 1, a hardness traverse through a welded section of NE8735 steel tubing (normalized prior to welding). The original normalized tube was about Rockwell C-25. At the conclusion of a pressure weld the temperature at the weld plane is approximately 2400° F. and tapers off at either side. The rate of subsequent cooling is sufficient to harden the metal that was heated above the critical, but the slightly subcritical temperatures existing some distance from the upset area account for a slight tempering or softening of the normalized tube. (Note hardnesses of C-16 and C-18.) "Tempering" is used here for the sake of describing the effect of heating the previously normalized structure to below the transformation temperature.

Converting hardness values to ultimate tensile strength, a theoretical value for the modulus of rupture for each area can be determined from curves given in the Army Airplane Design Handbook. The tubing from which the coupon was cut measured $3\frac{15}{16}$ o.d. x ¼ in. wall, which gives a diameter to wall thickness ratio (D/t) of 15.7.

Table I — Estimated Moduli of Rupture in As-Welded Tubes

	Unaffected Section	Tempered Section	Upset Section
Rockwell hardness	C-25	C-18	C-28
Tensile strength	125,000 psi.	107,000 psi.	131,000 psi.
Modulus of rupture	154,000 psi.	131,000 psi.	161,000 psi.

Moduli of rupture determined in this manner are shown in Table I.

Comparing the theoretical bending strength of the tube in the tempered section with that in the upset shows that the tempered section is about 81% as strong as in the upset. Actual tests bear out this reasoning; the tension sides of as-welded bend specimens show greater necking in the softer

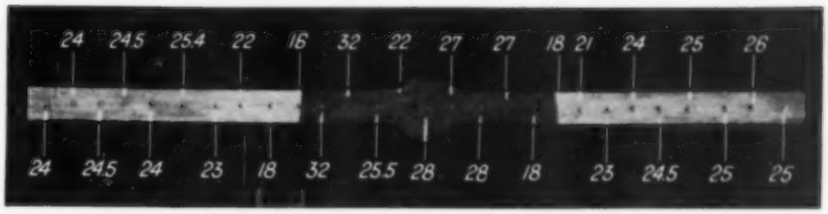


Fig. 1 — Hardness Traverse Along Wall of Normalized NE 8735 Steel Tubing After Welding but Before Heat Treatment. Three-quarters size

zones on either side of the weld with a corresponding increase in wall thickness in the compression sides. This is shown in Fig. 2. Therefore, bend specimens that fail in the weld at less than full tube strength after heat treatment, may fail by tube buckling or rupture when tested as-welded. Torch normalizing, though it decreases the hardness of the weld, does not eliminate the tempered areas of lower strength unless the whole tube is so normalized, because tempering will always occur in the metal at the edges of the zone heated by the torch.

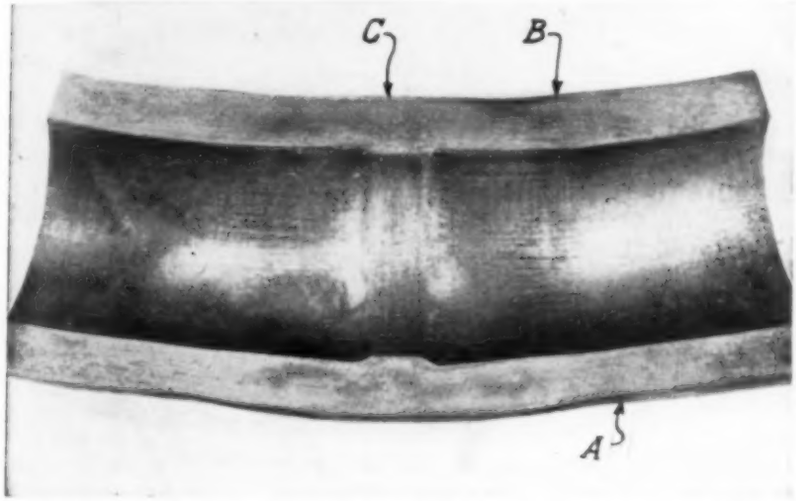


Fig. 2 — Section Through an As-Welded Pressure Weld After Bend Testing. Necking A in the tension side and wall thickening B in the compression side correspond to areas tempered by the heat of welding. The heavier section at C is part of the upset remaining after machining

Evaluation of pressure welds by tensile testing has several limitations. Coupons cut from welded tubing have not been very satisfactory because the coupon lacks the restraint that a full section tube has circumferentially. A coupon, therefore, has greater freedom to fail in angular shear without undergoing full tensile stress at the weld plane. See Fig. 3. Diagonal failure is particularly likely in coupons cut from tubing less than ¼ in. thick in the wall.

Likewise, heat treated welds of inferior quality which would tend to fail in static bending at a fairly high modulus of rupture but with low ductility would quite commonly fail in tension with apparent full strength and full ductility. Full sections of pressure welded tubing could be tested in tension were it not that only specimens with relatively small cross-sections can be tested in the usual laboratory machines. Very heavy sections can be handled in a bending test merely by making them long enough. Bend testing searches out areas of low strength if the specimen is loaded successively in several positions to below its yield point, thereby placing several limited areas of the weld in tension. When testing a full section, in tension, an average weld plane strength is determined,

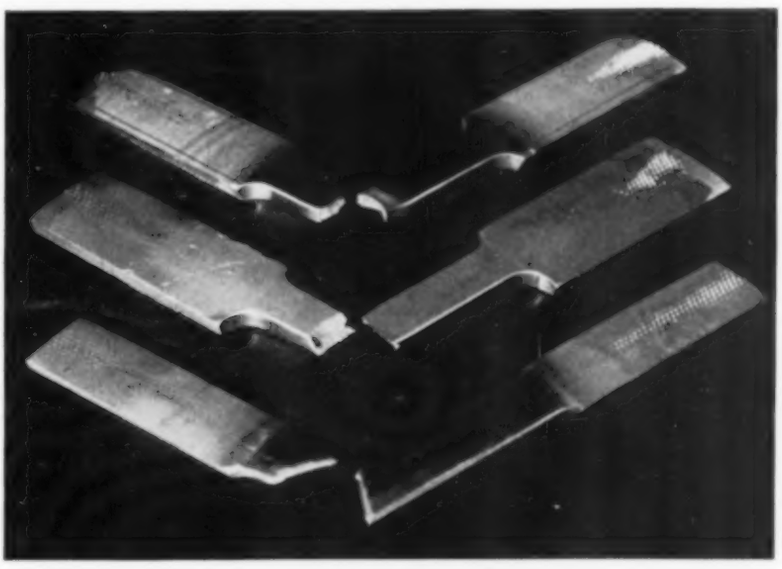


Fig. 3 — Three General Types of Failures That Occur When Uniwelded Coupons Are Tested in Tension. Whether there is some weld reinforcement in the form of upset partially remaining or not, a tensile failure in the plane of the weld is rarely encountered, even in welds of sub-standard quality

whereas bend testing places only a limited area under high tensile stress at one time and is, therefore, more effective in severely testing the weakest areas.

As the application of pressure welds is expanded, more critical tests may have to be devised for determining the quality of a particular weld for a particular application. Where high impact stresses are involved, the test would logically take the form of a shock or impact. Fatigue may also be a critical condition for some applications.

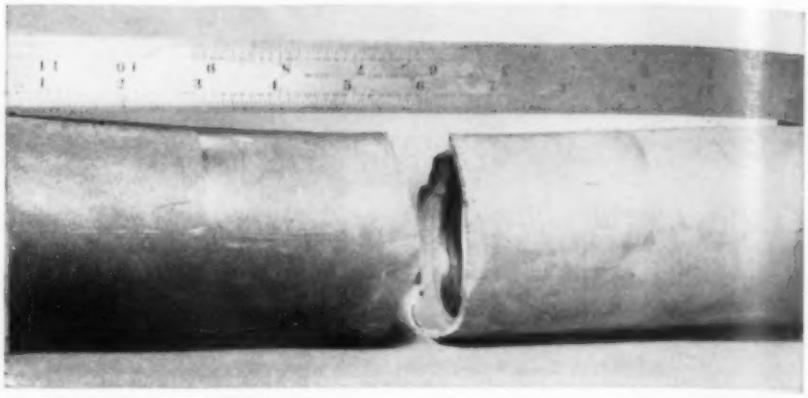


Fig. 4 — Good Weld After Fracture in Bending. Extreme tensile fiber is at bottom. Note that the fracture occurs after considerable deformation and passes partly through the base metal

Table II — Bending Tests on a Series of 100 Butt Welds

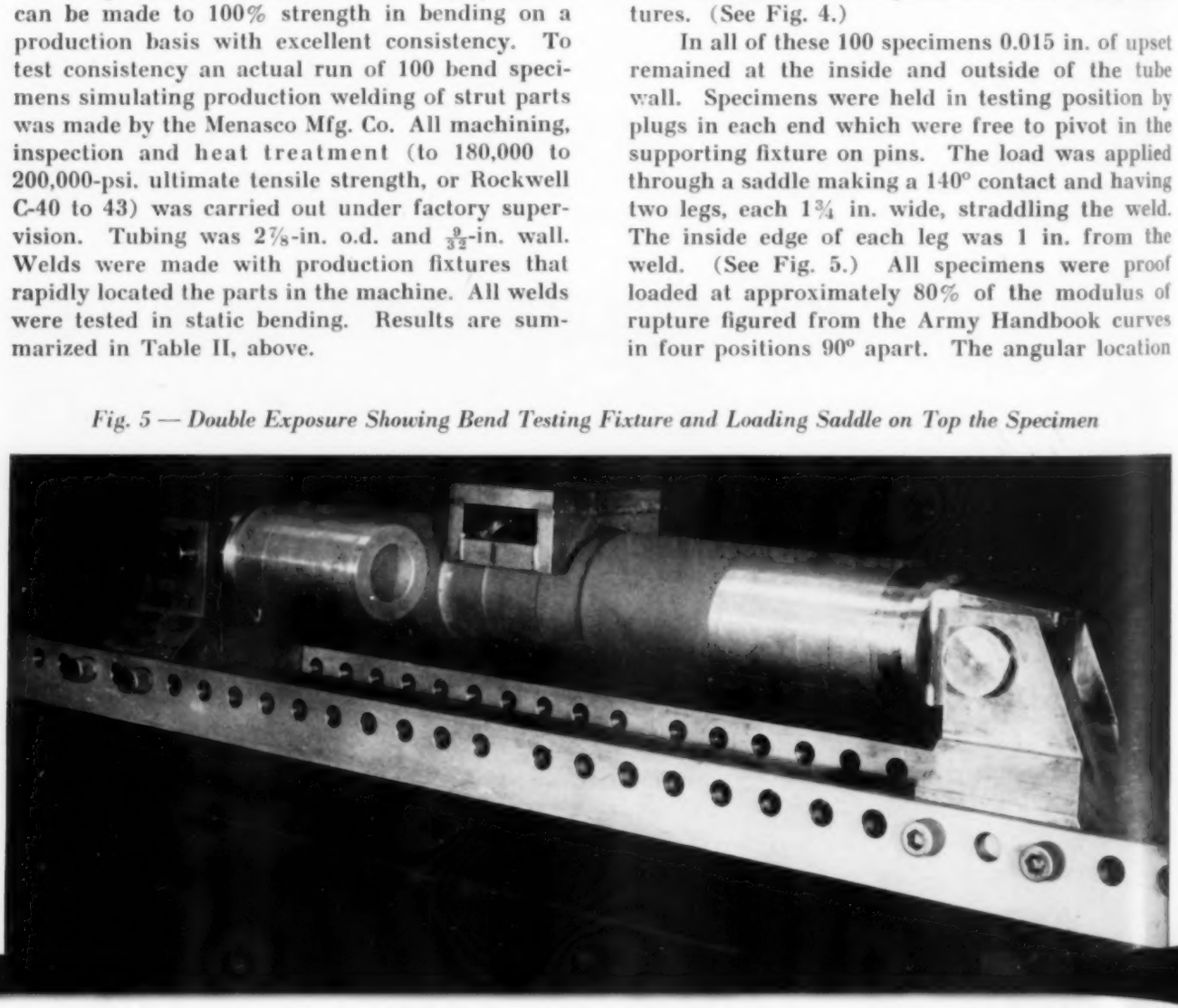
	Modulus of Rupture		
	By Test	From Curves	Actual ÷ Theoretical
Minimum	268,600 psi.	243,000 psi.	102%
Maximum	360,000	312,000	123
Average	322,000	285,000	113

At present, Uniwelds, even in heavy tubes, can be made to 100% strength in bending on a production basis with excellent consistency. To test consistency an actual run of 100 bend specimens simulating production welding of strut parts was made by the Menasco Mfg. Co. All machining, inspection and heat treatment (to 180,000 to 200,000-psi. ultimate tensile strength, or Rockwell C-40 to 43) was carried out under factory supervision. Tubing was 2⅞-in. o.d. and $\frac{9}{32}$-in. wall. Welds were made with production fixtures that rapidly located the parts in the machine. All welds were tested in static bending. Results are summarized in Table II, above.

Ninety-six of the failures were tube failures, of which 95 failed by buckling and one fractured at high strength at a slight undercut in the base metal. Four specimens fractured in the weld at high strength. Of these four specimens, two fractured at a value above that of the lowest tube failure, which was 106% of the modulus of rupture figured from curves in the Army Airplane Design Handbook. The lowest weld failure (102% of theoretical) broke at a figure which was 96% of the lowest buckling failure. All weld failures were combination weld plane and base metal fractures. (See Fig. 4.)

In all of these 100 specimens 0.015 in. of upset remained at the inside and outside of the tube wall. Specimens were held in testing position by plugs in each end which were free to pivot in the supporting fixture on pins. The load was applied through a saddle making a 140° contact and having two legs, each 1¾ in. wide, straddling the weld. The inside edge of each leg was 1 in. from the weld. (See Fig. 5.) All specimens were proof loaded at approximately 80% of the modulus of rupture figured from the Army Handbook curves in four positions 90° apart. The angular location

Fig. 5 — Double Exposure Showing Bend Testing Fixture and Loading Saddle on Top the Specimen



of the side in tension at failure was varied with each specimen.

Since we were mainly interested in the strength of a Uniweld as compared with the strength of the tube, the testing fixture and saddles were designed to meet practical requirements of testing butt welded specimens rather than to duplicate any standard bend test specification. Therefore, the calculations in the tables based on Army Airplane Design Handbook are intended only as a comparison between specimens.

To compare static bend strength of Uniwelds and electric arc welds heat treated to the same range of tensile strength, five electric welds were

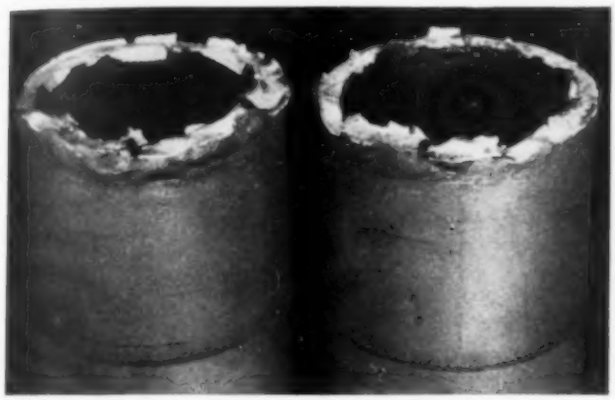


Fig. 6 — Typical Fracture (Bending) of Arc Welded and Heat Treated Butt Joint

made using the same size specimens and the same heat of steel as those in the test run of 100 described above. Two brands of high tensile welding rod, used in experimental and production welding on landing gear assemblies, were selected. Specimens were prepared with double 45° chamfers, preheated to 750° F., welded in three passes, heat treated to 180,000 to 200,000-psi. tensile strength and tested in bending in the same manner as the test run of 100 Uniwelds. Excess weld metal amounting to an average of 0.045 in. over the wall thickness of the tube remained on the test pieces. These electric arc welds, even though considered of high quality, gave poor results, as shown in Table III on page 534.

None of the five specimens survived proof loads in four positions, although specimen B was taken to the third position before fracture took place. The weld that had the highest strength tested 64% of the average strength of the test run of the 100 Uniwelds, the arc weld having the lowest strength testing only 51% tube strength. Figure 6 shows one of the weld fractures which is typical of the five.

It has been observed that specimens which fracture either in the base metal or weld plane usually fail at a lower stress than those that buckle. A run of eight Uniweld bend specimens ($4\frac{1}{8}$-in. o.d. x $\frac{17}{32}$-in. wall, made of 4340 steel) illustrates this point. A typical example is the specimen failing by base metal fracture and at a lower modulus of rupture than the other specimens which failed by buckling. (See Table IV on page 535 and Fig. 7, below.)

Determination of Welding Settings

Owing to the inherent interdependence of various controlling factors, Uniwelding has not been reduced to a basis from which new sizes of tubing can be welded using pre-calculated machine settings. Settings are empirically determined. To acquaint others with the general procedure the method for securing satisfactory results on an untried size will be described.

The first step is to procure a torch adequate for the weld. A single torch is not restricted to a single size of tubing, but can be used for a range of sizes. Depending on results heretofore secured with other torches, design takes into consideration the size, number, and spacing of orifices, the dis-

Fig. 7—Fracture in Base Metal (Bend Specimen). The Uniweld is located half way between burnished markings caused by loading saddle

tance from orifice to work, size of main gas passage and water passage, and the exterior geometry.

Short specimens (about 24 in. long after welding) are then machined to reproduce the outside and inside diameter of the actual part to be welded, and also the general geometry and mass distribution in the vicinity of the weld. This latter requirement is very pertinent inasmuch as welds made in straight tubular sections may differ considerably from those made in sections which have slightly heavier walls adjacent to the weld,

since the latter change the heat input requirements. These trial specimens are welded according to empirical data derived from experience and then sectioned to determine metallurgical characteristics which can be interpreted in terms of expected physical properties. Various considerations in designing the geometry of weld faces and in making a weld are outlined as follows:

1. The geometry of the weld face should be such that faces butt together tightly to exclude air during welding, and chamfered so as to secure a desired balance between the size of internal and external upsets and to secure smooth flowlines in the upsets. (Figure 3 in the article last month shows a typical chamfered face before welding.)

2. The surface finish of butting faces is lathe turned and normally held to 50 to 500 micro-inches (root mean square). Thin-walled welds require the finer finishes, whereas heavy-walled welds can tolerate the coarser ones.

3. The amount of heat and pressure during welding are interdependent and the essential requirement is to secure a proper balance between them so as to permit good bonding without belling.

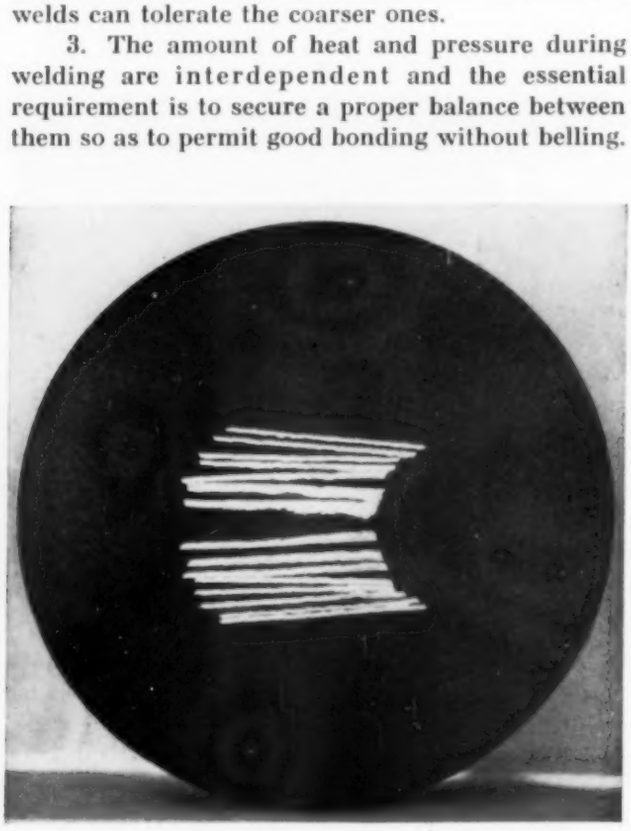


Fig. 9 — Chip Mounted in Plastic and Cut Down to Show Cross-Sections

Table III — Tests on Five Arc Welded Tubes After Heat Treatment

Specimen	Modulus of Rupture			Location of Failure
	By Test	By Formula	Actual ÷ Theoretical	
A	180,000 psi.	272,000 psi.	66%	Weld
B	191,000	265,000	72	Weld
C	159,200	275,000	58	Weld
D	188,500	275,000	69	Weld
E	165,500	249,000	66	Weld

Fig. 8 — Type of Chip Obtained From Internal Upset for Microscopic Examination. 4 ×

(Belling is a bulging outward of the tube in the region of the weld.) The tendency of a weld to bell increases as the wall thickness decreases and also as the ratio of diameter to wall thickness becomes smaller. Belling is held in check by a sufficiently high rate of heating with high enough pressure to upset the metal before much of the surface melts. On the other hand, the heating rate and the upsetting pressure must be kept within the range for good bonding. Welds in heavy walls must be made at lower heating rates and lower upsetting pressures to minimize temperature differences between inside and outside. Pressures usually range from 4000 to 6000 psi.

4. The amount of gather (shortening of the part in welding) should be sufficient to form upsets which are high enough so any fissure which may occur in the internal upset and the relatively small amount of burning in the external upset may be machined away. Also sufficient gather must occur to assure good bonding.

5. The structural and design requirements of the section govern the weld to a very considerable extent.

For instance, the ordinary procedure is for internal and external upsets to be machined to within 0.015 in. of the wall when the weld does not make contact with other members. In that case, the belling may be more extensive than when the entire external surface of the welded parts is to be machined away, for then the amount of belling is effectively a loss in finished wall thickness. Also, external metal that has melted or has suffered intergranular burning must be removed. Similarly, when the entire internal and external tube surfaces are machined away, belling must be sufficiently small to permit internal cleanup. Variation in heat, pressure, and gather therefore

Table IV — **Strength of Buckled Versus Fractured Tubes**

Tensile Strength*	Modulus of Rupture			Type of Failure
	By Test	By Formula	Actual ÷ Theoretical	
200,000 psi.	306,000 psi.	305,000 psi.	100.5%	Buckling
196,000	304,000	301,000	101	Buckling
198,000	292,000	303,000	96.5	Base metal fracture
190,000	298,000	293,000	101.5	Buckling
200,000	305,000	303,800	100.5	Buckling
198,000	311,500	303,000	103	Buckling
198,000	304,000	303,000	100	Buckling
190,000	296,000	293,000	101	Buckling

*Computed from hardness.

depend, to a certain extent, on the design requirements of the weld.

After due consideration of these various factors, adjustments are made until the test specimens are satisfactory on a visual basis. Laboratory evaluation then follows, by both microscopic examination and by fracturing coupons cut from the welds. (Hammer fracturing is a rapid qualitative method.) The various points examined are depth of fissure, if present, the amount such a fissure propagates in heat treatment, the depth and intensity of oxygen-rich areas, amount of melting on the outside surface, and depth of intergranular burning. A decision is then made as to whether or not the weld is satisfactory for the desired application. If it is not, corrective measures are taken on additional specimens until proper results are secured.

After approval of the trial weld, full-sized static bend test specimens are welded under the same general conditions as surrounded the making of the approved metallurgical specimen. Heat treatment by oil quenching and drawing to the desired tensile range, plus machining to the same dimensions as the corresponding section of the actual structural part, follow welding. During this processing, welds are closely inspected as outlined below. These welds are then statically bend tested, and the results govern whether or not the finished parts can be welded using the same machine settings. If results are acceptable the structural parts are welded.

Inspection Methods

Open Tube Assemblies — The methods now used to insure sound welds consist of inspection during welding operations to insure that welds are made under the same conditions as the approved metallurgical and bend test specimens, and metallographic and magnetic inspection after welding and machining of the internal and external upsets.

Magnetic inspection is done by magnetizing the Uniwelds in a coil. Indications on the internal upset are detected by a magnifying mirror especially illuminated and constructed. A fine finish on machined upsets is desirable, inasmuch as deep tool marks give false magnetic indications. Magnetic inspection will reveal both internal and external fissures if they are present.

There was recently placed in production a new inspection method developed by the authors for metallographically evaluating each weld. This method is yielding excellent results and is expected

Fig. 10 — Unetched; Chip Showing a Propagated Fissure. 100 ×

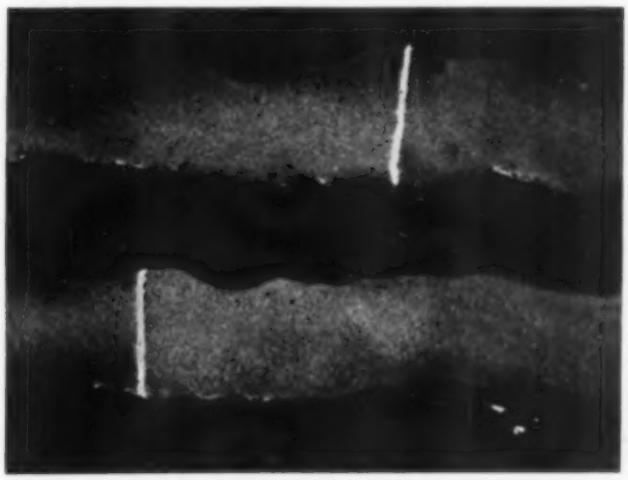


Fig. 11 — Chip Containing a Weld Plane of High Oxygen Concentration, as Shown by Etching in Alkaline Chromate Solution. 100 ×

ultimately to replace internal magnetic inspection. It consists of machining the internal upsets almost to finished size and then removing a tightly curled chip in one or two revolutions of the part (Fig. 8), this chip being approximately 0.020 in. thick, cut with a special flat tool. Chips are then mounted in bakelite with an element of the cylinder parallel to the surface to be polished. This is then deeply ground and polished so that several cross-sections of the curl are exposed (Fig. 9, page 534). The surface is then examined unetched for fissures and later etched with alkaline chromate and examined for both fissures and oxygen concentration (Fig. 10 and 11, page 535). Observations which can be made in this way are:

1. A deep fissure will produce a wholly or partially split chip, and if the fissure exists only part way around the internal upset of the weld, the chip segments representing the fissured portion will show either a completely or partially split chip.

2. Light-etching zones of high oxygen concentration may be revealed. If present in sufficient amounts they indicate welds possessing undesirable metallurgical characteristics. Such a conclusion is considered valid because it has been found from past experience that the quality of the internal upset is a reliable index of the quality of the whole weld.

The value of such chip inspection lies in the fact that in one step it reveals oxygen concentration at the weld and the possible presence of fissures. Magnetic inspection, which is subject to considerable interpretation, reveals fissures only.

Closed Tube Assemblies — Closed tube Uniwelds, that is, those welds which are not accessible for internal machining, are sometimes used in airplane struts. Because inside inspection is impossible, special geometry of the weld faces can eliminate internal fissures. Such procedure is avoided when making welds in open end tubes because the cost is somewhat higher.

Conclusions

1. Uniwelding gives the design engineer a weld which can, section for section, meet the requirements demanded of the base metal.

2. Since no weld metal is added nor is the analysis of the metal at the weld altered, the weld zone responds to heat treatment identically to the base metal.

3. Although welds in walls no heavier than $\frac{9}{16}$ in. and in tubes no larger than 10 in. diameter have been welded at Menasco Mfg. Co., there is good reason to believe that much heavier welds can be successfully made. High quality welds in thin walls ($\frac{1}{8}$ in. or less) become progressively more difficult to make.

4. Welding equipment is relatively simple, although proper design is mandatory. The method of heating involves no great investment nor great power peak or standby facilities.

5. Various low and medium alloy steels such as 4130, 8740, and 4340 respond identically with respect to weld quality to one set of welding conditions, and the range of materials that can be welded satisfactorily appears to be very great.

6. Each open end weld can be inspected individually.

Bits and Pieces

First-Piece and Patrol Inspection

LOT-BY-LOT inspection, as developed by the Army Ordnance Dept. for ammunition and fuse parts, is highly efficient, but frequently involves such high costs that for peacetime uses the methods may be unwarranted, even after crediting the value of obvious benefits to subsequent assembly operations. A more "commercial" solution may reside in a mixture of first-piece and patrol inspection procedures using statistical methods, with some lot-by-lot inspection with screening where necessary.

For example, when a machine or group of machines is set up for continuous production on a single item, as often happens in the manufacture of domestic refrigerators, an inspection station will be located at the group of machines. At regular intervals, perhaps once an hour, a patrol inspector will visit this station bringing with him checking masters to verify the gages which have been provided for joint use of the operators and the inspector. He will check pieces as they come from the machine and if they are found correct, dispatch the production since the last previous check to the next operation. If he finds defects, or if there is any other cause for suspicion, he will

at the same time, sample the production which has accumulated since the last previous check. If this sample discloses more than a predetermined number of defects, or defects greater than a predetermined magnitude, that lot of work will be routed to a bench inspector where the defectives will be screened out.

The advantages and opportunities with this scheme will be an increase in the operator's responsibility for quality; an improved control over maintenance of equipment and tooling; an improved correlation of observations on consecutive groups of parts, so that any growth in defective work can be quickly curbed and easily corrected by screening. The net result will be a definite improvement in the quality of the products. (A. L. ATHERTON, supervisor of quality control, Westinghouse Electric Corp.)

Accurate Hardness Surveys

SEVERAL expedients have been noted in past issues of *Metal Progress* to insure that the hardenability bar is properly seated in the hardness tester, so the Rockwell readings will really be accurate. It has been our practice to place a Rockwell standard test block on top the Jominy test bar and take readings until the machine checks within the limits of the standard block. Ordinarily two or three readings are sufficient to assure us that the Jominy bar is seated properly in the fixture and that the penetrator is in good condition. (J. A. ERICKSON, metallurgist, Electro Motive Division, General Motors Corp.)

Removing Carbide Tips From Tool Shanks

A SOLUTION of 80% nitric acid in 20% water at 175 to 195° F. is very useful for removing brazed carbide inserts from steel shanks. The carbide is not attacked by the solution, neither is the shank. The latter is clean and can be retipped without machining. It takes from 30 to 90 min. depending on the size of the tool. Some precautions are necessary:

1. Preheat the tool to 200° F.; otherwise violent foaming will occur.
2. Place the tool so the tip falls out as soon as it is loose.
3. If the tool is removed for inspection, wash and reheat it before putting it back into the hot acid.
4. Immerse only a little beyond the tip.

Some obvious precautions are necessary. The operator should wear goggles, acidproof gloves and apron, and keep some commercial ammonia handy to dash on any accidental splash reaching the person. Fumes should be carried off through a hood. Handle acid in stainless steel beakers; they have no hazard from breakage. (R. G. MAURER, headquarters manufacturing engineering department, Westinghouse Electric Corp.)

Electropolishing Without Rounding the Edges

IN our laboratory we must examine the cross-section of many rods and wires out to the very surface. It therefore became imperative that some method be obtained of electropolishing these specimens and at the same time prevent the edge rounding, which normally accompanies the process, from exceeding a certain minimum amount. The maximum edge rounding acceptable was such that the edges could be examined easily and with certainty at 100 diameters. The problem was solved by wrapping each piece with 0.004-in. strip.

We cut rectangular pieces of this dead-soft steel strip; one dimension about equals the length of our specimen, the other wraps around the rod with ½ in. to spare. A piece is then tightly wrapped around the cylindrical surface of the sample in a manner so that one edge protrudes $\frac{1}{32}$ in. beyond the edges of the transverse section of the bar sample to be electropolished. The strip is easily held in position by merely pulling it up tight with a pair of pliers, flanging the ends out, and clamping them together with a cotter pin or a paper clip. The surface to be polished should be immersed only slightly below the surface of the electrolyte.

This method of preparing the sample for electropolishing, though it may appear somewhat complicated, can be accomplished easily by any laboratory assistant in a minute or less. All the material and tools necessary are a small pair of metal shears, a pair of pliers, a few cotter pins or paper clips, and some dead-soft thin strip steel between 0.003 and 0.006 in. thick. It can be used on shapes such as hexagons and half-rounds with the same facility as for rounds. As long as the strip steel is tightly wound, and as long as it extends some distance beyond the surface to be polished, the rounding of the edges will be much

less than if the sample is electropolished without any such preliminary. When computing the necessary current, allowances must be made for both the inside and outside surfaces of the strip which are immersed in the solution. (JOHN M. KIEFER, laboratory supervisor, American Steel & Wire Co.)

Adhesive Tension Patch

TESTING ENGINEERS in industry will undoubtedly have occasion to put to good use the technique developed by the structures test unit of the Air Technical Service Command, U. S. Army, by which a uniformly distributed load can be hung to the under-side — or affixed to the upper-side, for that matter — of a sheet. We have used it extensively for testing airplane wings by hanging a system of static loads to their under-surfaces.

The sponge sheet used in our static tests is of high tensile neoprene, has a density of 0.215 and a thickness of 1 in. It is supplied by the Sponge Rubber Products Co. of Derby, Conn. Since a synthetic sponge of this type has been known to increase its thickness as much as 100% where the structure being tested is loaded to the ultimate, deep skin wrinkles forming in the metal cover of the wing do not have any bad effect on the holding power of the tension patch while the load is being applied. Another very good feature is that after having been bonded to an airfoil it is not affected by oil or hydraulic fluid.

The neoprene base cement, for bonding the pad to metal, is manufactured by the Minnesota Mining Co. of Detroit, and is known as Type EC-613. To use the cement successfully, all surfaces must be free from grease and dirt. The technique of cementing is quickly learned, although the curing time requires 48 hr. or longer, according to the moisture content of the air. This cement can be stored for months without coagulation. It is stable, can be applied with a paint brush quickly, and can be thinned with toluene substitute to the proper consistency. If the cement is allowed to set or dry too long before the adhesive tension patches could be put into place, the areas can be reactivated by applying a thin coat of toluene substitute.

By the combination of these two materials, a safe working tension load of 2000 psi. has been developed. These loads have been supported continuously for 72 hr. without failure of the sponge sheet or the cement.

This method of loading aircraft structures by the use of adhesive tension or compression pads is covered by patent No. 2,383,491, in which the Government has a royalty-free license, and the inventors retain all rights for commercial exploitation. (E. R. WEAVER, civilian director of structures test unit, Air Technical Service Command)

Continuous Induction Hardening

FOR nearly three years, Caterpillar Tractor Co. has been hardening continuously, by induction heating (plus quenching and tempering), bar stock from ½ to 1¾ in. in diameter and in full bar lengths. The original conception of the method and process was given by our engineers to the Ohio Crankshaft Co. That firm, in turn, demonstrated its feasibility and later constructed the equipment now used by us.

The process may be typically described in the handling of ⅞-in. rounds. The bars are 18 to 20 ft. long, and are of S.A.E. 1035 steel selected for correct hardenability for the parts and the sizes involved. The heat treated bars are eventually machined to produce studs, bolts, tie rods, and other items in a hardness range of C-20 to 26.

The bars pass endwise down a roller table and are guided through a heating coil at such a rate that they attain a temperature of about 1600° F. Immediately beyond the induction coil they are struck by a conical convergent stream of water at controlled temperature (between 80 and 90° F.) and pressure. Splash is avoided by a proper housing. After quenching, the bars pass on continuously through a reheating coil, also an induction coil, where they reach a temperature throughout of about 1125° F. Thence, the bars pass on to the conveying system and are cooled enroute while being returned to storage.

Provision was made for introducing a protective atmosphere in the heating coil to prevent scaling. Even without this protective gas, scaling is very slight, for the time at heat is quite short.

The physical characteristics of the bars so treated show improvement over former conventional practices, giving yield strengths in the vicinity of 90,000 to 105,000 psi., ultimates of 115,000 to 130,000 psi., elongations of 23 to 28%, reduction of areas of 62 to 66%, and Izod tests on sharp-notch, round bars of 80 to 100 ft-lb.

Bars ⅞ in. in diameter and larger require little straightening after heat treatment. Smaller sizes are run through a Medart straightener after hardening.

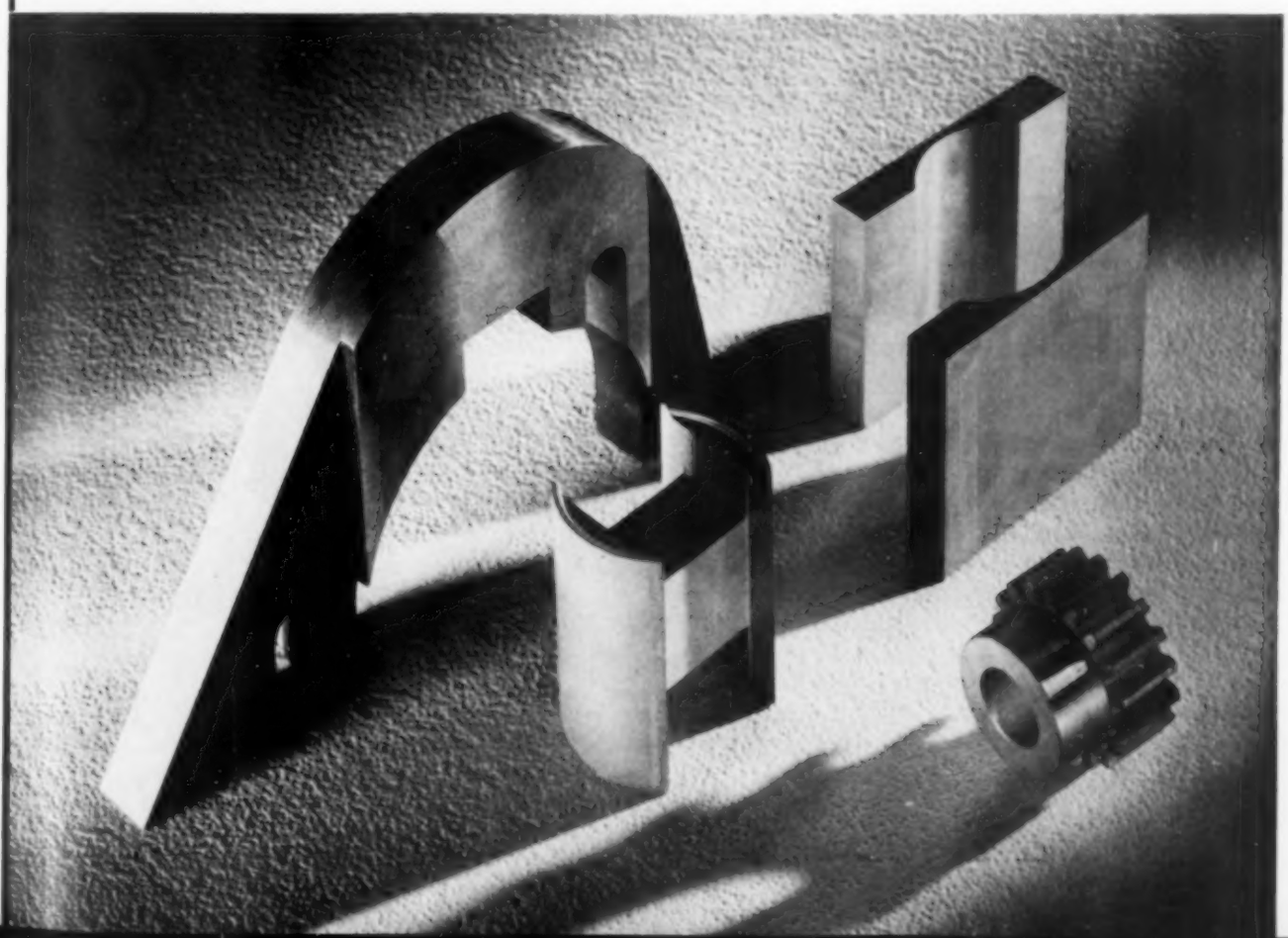
The improved quality, the immediate availability of heat treated bars, and the overall economy of the operation, have been quite satisfactory. We have several of the units in operation. (E. E. ALEXANDER, metallurgical department, Caterpillar Tractor Co.)

Parts From Powders

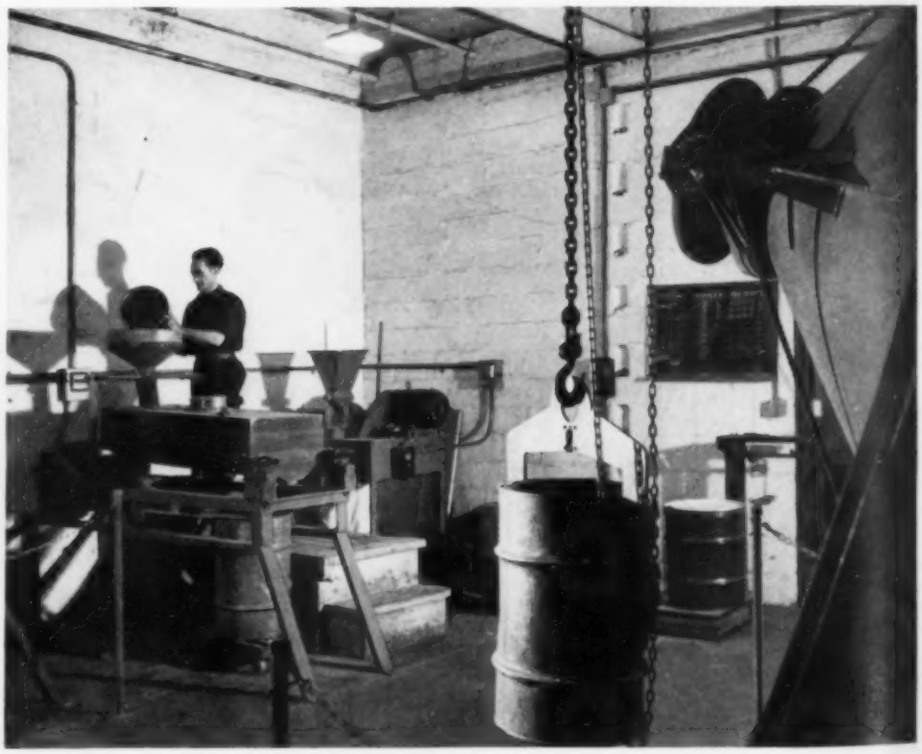
Manufacture of Ferrous Metal Powder Parts

Pictorial Story Photographed by F. M. Demarest at Plant of American Electro Metal Corp., Yonkers, N. Y.
Text by Paul Schwarzkopf and Claus G. Goetzel

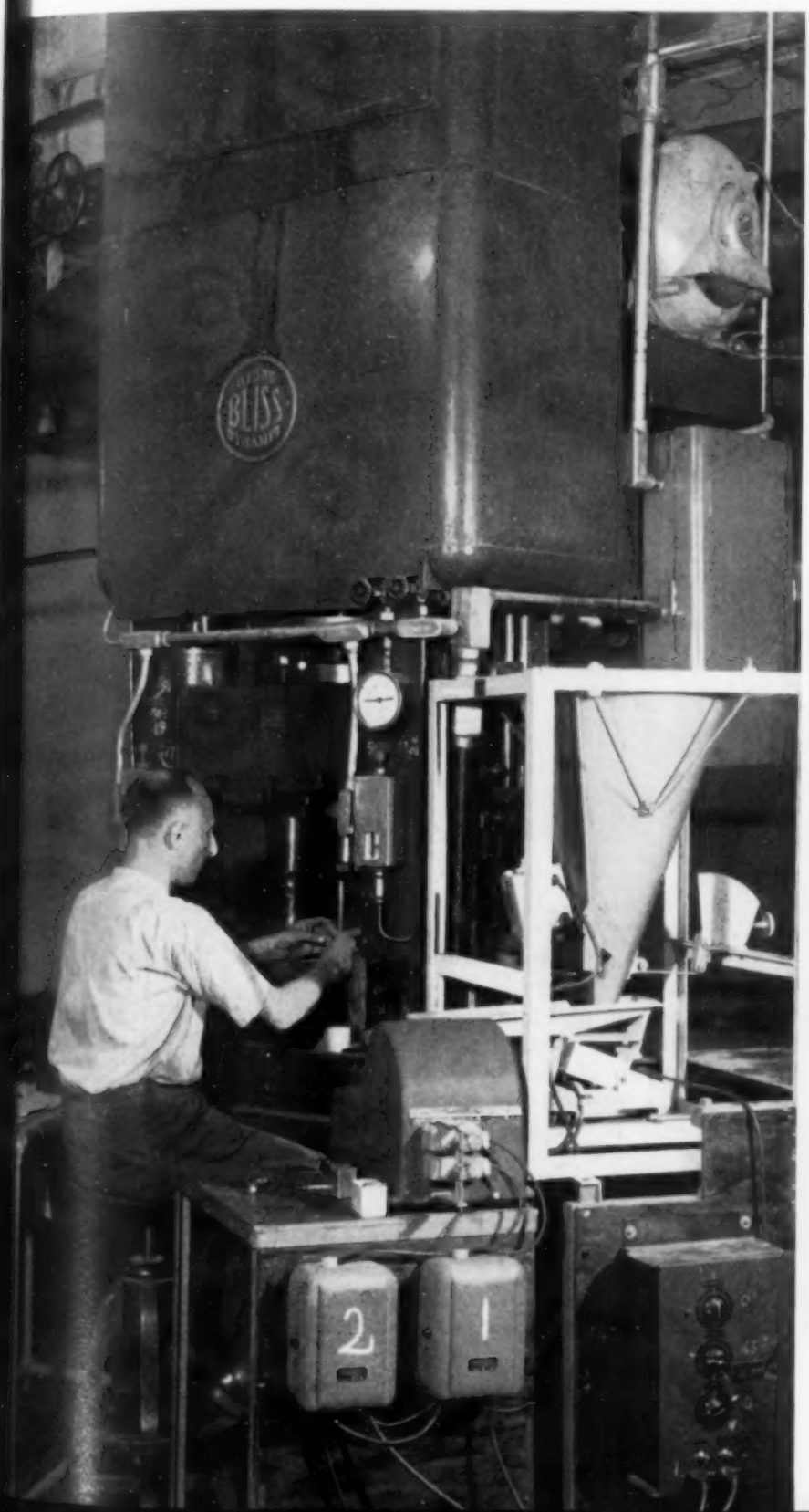
POWDER METALLURGY of iron and steel has made considerable progress in recent years. At present, iron powder is used as principal raw material for the manufacture of many structural and magnetic parts; during the war it also produced certain expendable munitions, parts for arms and general ordnance articles. Parts ordinarily made by extensive machining of steel bar stock or castings have been replaced effectively by powder products, especially designs which require accurate configurations most of all. For such designs, as a matter of fact, the high mechanical properties that accompany standard iron and steel products are often overrated.....The powder metallurgy process consists essentially of a series of steps including conditioning the powder for cold molding, molding in automatic presses, making the compacts metallic by sintering at high temperatures in protective atmospheres, re-pressing or coining the blanks into final accurate shape, and heat treating and otherwise finishing the parts to render them useful for assembly and service.....The steps to be described produce such parts as are shown below.

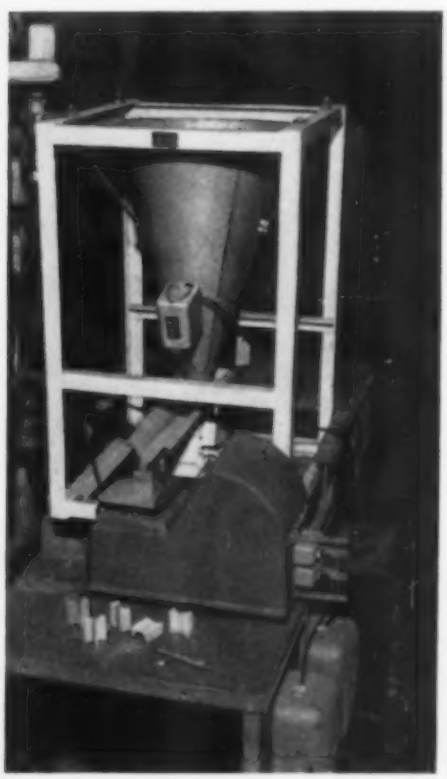


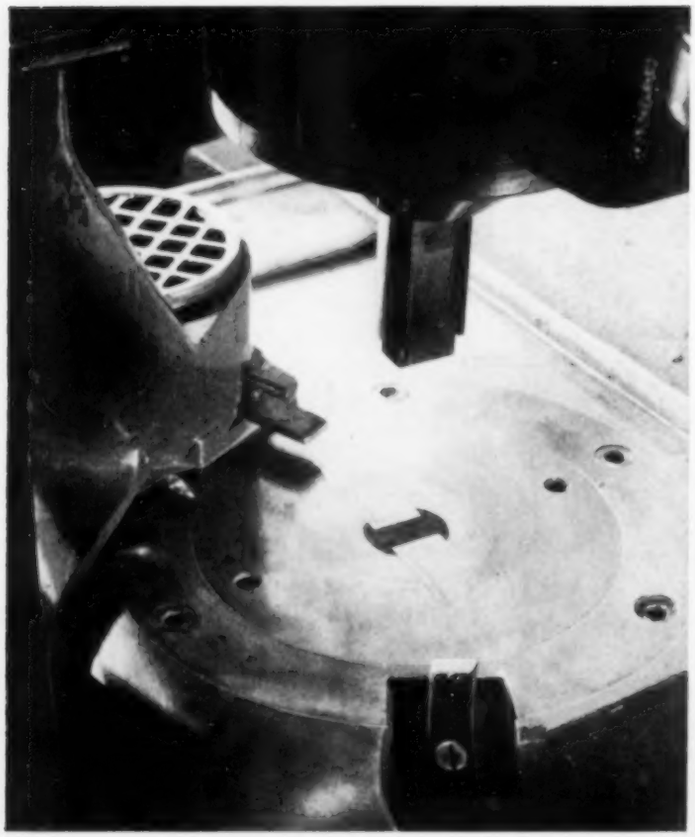
Metal powders are received in drums tightly sealed to prevent excessive surface oxidation of the particles during shipment. The content of each drum is sampled for routine laboratory control work and a screen analysis. These samples are tested in the laboratory to determine their important physical and chemical characteristics. Of particular significance are the powder's apparent density and flow rate for uniform fill of the die cavity, and its freedom from harmful chemical impurities, notably oxygen, carbon and acid insoluble inclusions.....Small sample lots, representing a fraction of the final production lot, are composed of the individual screened batches. To achieve uniformity, they are blended in a tumbler of laboratory size. The sample lot serves solely for control testing of certain important properties, such as compactability, and for setting the tools of the briquetting machinery. .....Production allotments are then apportioned by weighing the necessary quantities of metal powders, either for uniform blends or for desired alloy compositions. Often non-metallic additions are made to facilitate briquetting or sintering. Lots of one to three tons of powder are prepared by first screening through a stabilized gyrating 100-mesh screen (at left in the photograph at the bottom of this page). Any non-metallic addition agent is simultaneously screened into the mass, intimate particle-to-particle contact being assured by the large surface of the spread-out powder in the sieve. Tumbling in a large cone blender (at extreme right) completely homogenizes the powder mixture. Final sampling must show results comparable to those obtained with the first sample lot. Powder is then stored in closed containers ready for processing.



When making precision parts with tolerances of a few thousandths of an inch in every direction, it is sometimes preferable to fill the die with a weighed amount of powder, as the effects of variations of density, flow and purity of the powder are minimized by this method. Such briquettes are formed at the rate of three to five per minute in this process on account of the time required for manual feeding. A hydraulic press can be used advantageously if high molding pressures are necessary.....As shown by the operator at the machine at left, the powder is poured into the cavity and spread evenly to distribute the particles uniformly. After pressing, the briquette is automatically ejected from the die, and the operator removes it before refilling. While he is emptying the powder into the die, another container is filled automatically with new powder.....The weighing apparatus shown alongside the machine, and from another angle below, is entirely automatic. The powder is stored in a feed hopper and passes over a chute into a small metal container. Vibration of hopper and chute causes the powder to flow; when the exact weight is reached in the container, the vibration stops. The cut-out is controlled by relays activated by photoelectric cells on the scale. At the rate of four to five weighings per minute, accuracy is within a variation of 1% up to a weight of five ounces.

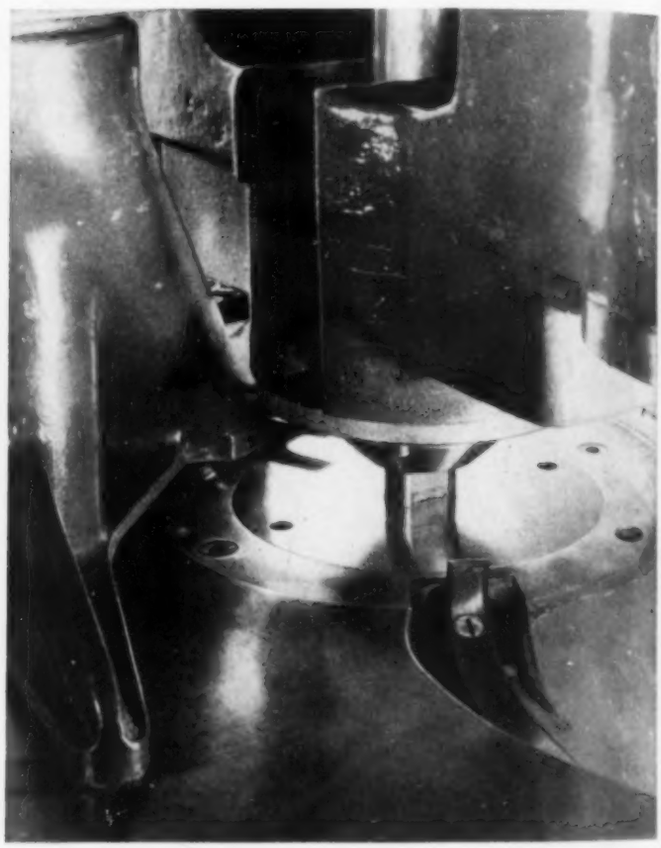






The Die Is Filled and the Filling Shoe Swung Aside to Clear Punch

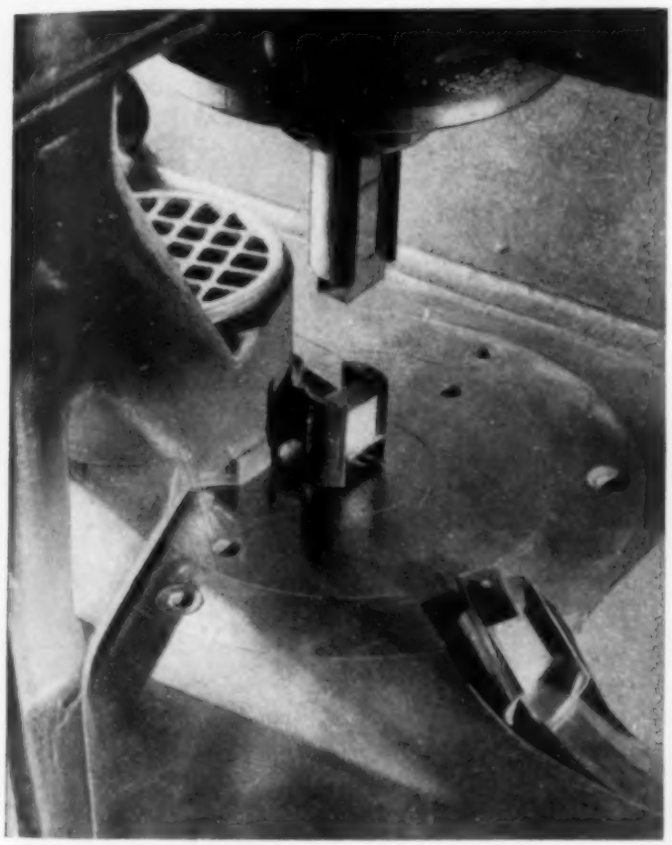
Upper Punch Squeezes the Powder Into the Die



While hand feeding, as shown on the preceding page, is best for high precision and useful for short runs as well, mass production almost requires an automatic feeding device. Such devices are by no means confined to the production of simple shapes.....Pieces having several thickness levels can be molded into uniformly dense cross-sections only in mechanical presses which activate several telescoping punches, both from top and bottom. By individual movements of the punches powder is transferred into different sections of the die, as required for uniformity.....The powder is filled into a feed hopper and passes through a feed shoe into the die cavity, filling it flush with the top of the die, as shown at top, left. Then the individual punches, top and bottom, will move towards each other, thus compressing the powder into a coherent shape. The bottom of the stroke is shown above, at right. The formed compact is automatically ejected when the lower punches raise it up to the level of the feed plate (at left on the opposite page) and pushed away onto an inclined slide by the feed shoe as it fills in fresh powder (final view).....This type of volume feeding assures equal fill-mass with each consecutive press cycle, if the powder is uniform in its physical characteristics.

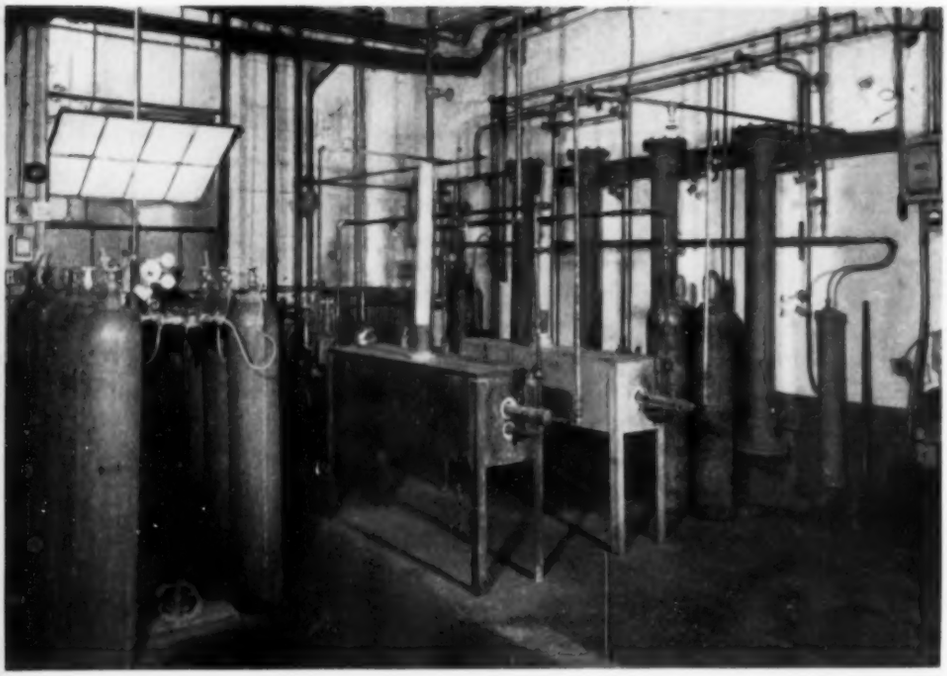
Complicated Shapes

Whether made by hand feeding or by automatic feeding, the pressed compacts, commonly referred to as "green" pieces, are now ready for heat treatment. The furnaces are either gas heated or electrically heated, and examples are shown on the next page. Green pieces are transported on a conveyer or on carriages to the furnace department. Frequently it is advisable to divide heat treating into two stages. A presintering operation at approximately 1500° F. permits the slow and uniform heating necessary for driving out the included gases and any reaction products arising from the addition agents. A high sintering operation then consolidates the briquettes into strong metallic bodies, by a process wherein the individual particles of powder diffuse mutually at all contacting points.



Compact Formed and Ejected by Upward Motion of Bottom Punch

Bottom Punch Has Receded, Upper Punch Raised, and Filling Shoe Swung Over to Load a New Charge of Powder Into the Die

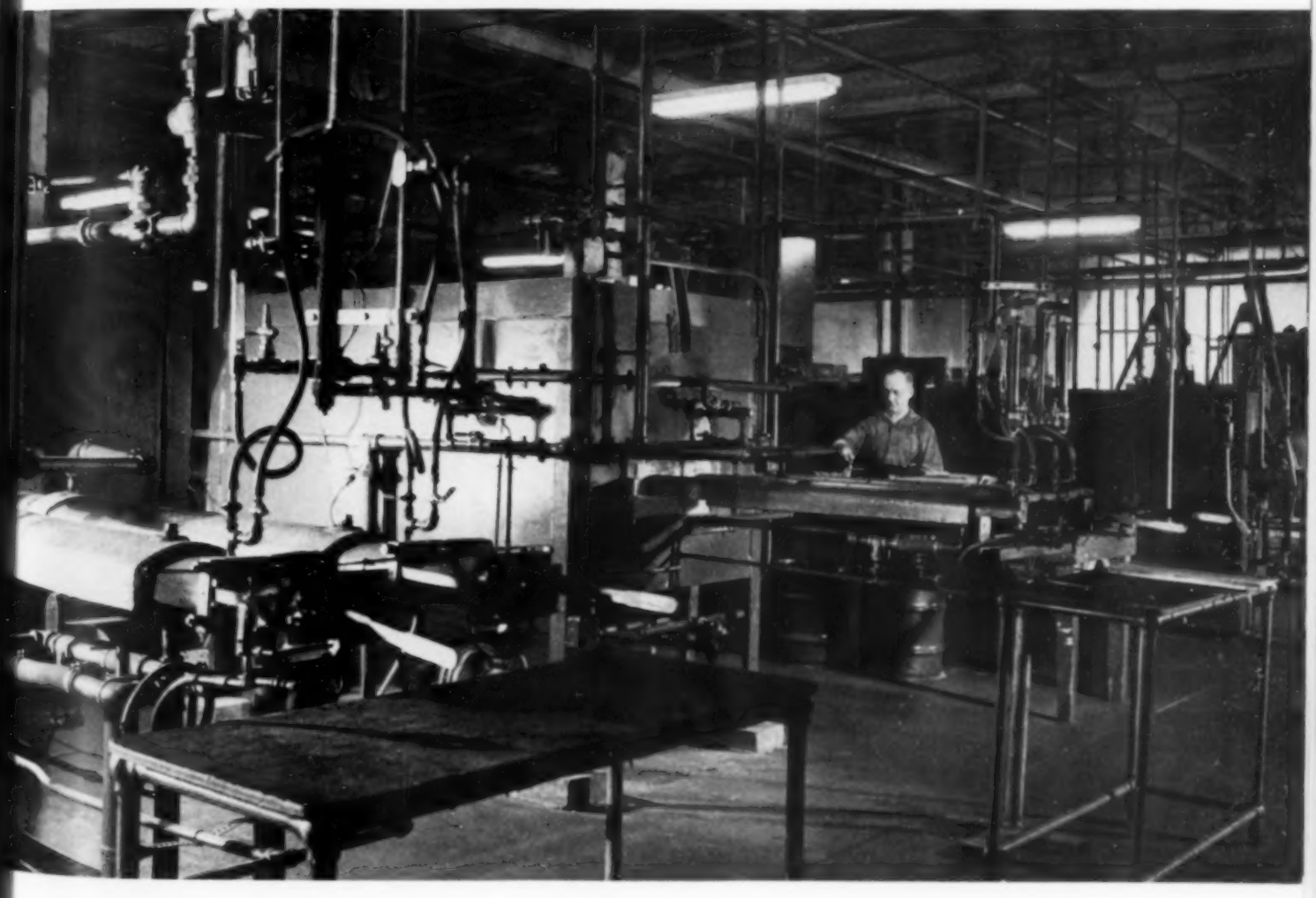


Atmosphere Plant

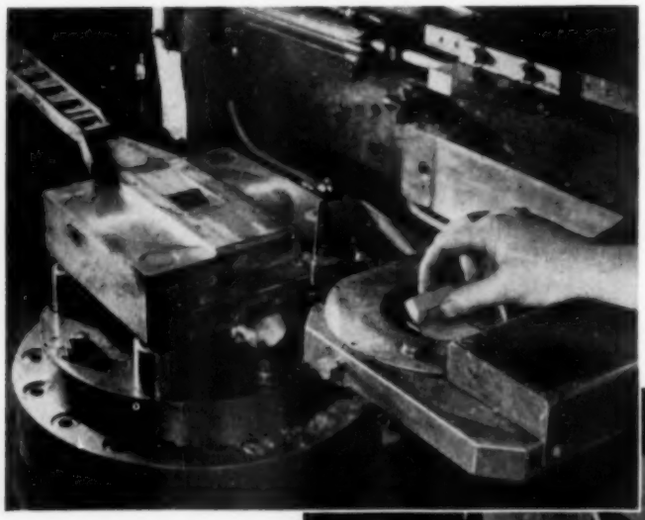
All heat treatments of commercially important metal powder parts must be carried out in protective atmosphere. Because of a certain porosity in them, a considerably larger surface area is exposed than with regular wrought or cast metal. Consequently a high heat in air would completely oxidize the piece throughout its cross-section. Even a "neutral" atmosphere would not be completely satisfactory, as small amounts of air, entrapped within the particles or in the interstices, cannot be removed easily and would then react and contaminate the structure. Hence, strongly reducing atmospheres are most effective.....Hydrogen, cracked ammonia, natural gas, or partially combusted hydrocarbons

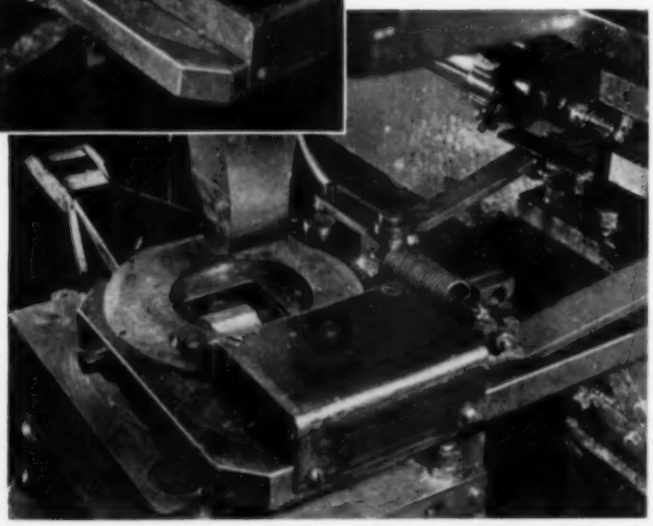
can all be adopted for the process. Their purity, however, is essential and must be most carefully guarded. Any excess of a valuable gas such as hydrogen — not used up in the reaction with residual oxygen in the powder or lost through leaks and open doors — is recovered by a recirculation and purification system. Passed over hot copper, commercial hydrogen from cylinders is purified of all oxygen, forming water which is then removed with caustic potash in drying towers.

For heat treatment, the most economical furnaces are of the continuous transport type, as shown below (entrance end at left, discharge end at right). The charge may be passed on a conveyer belt, may travel on trays over power-driven rollers, or may move on trays pushed one ahead of the other by mechanical or hydraulic means. The furnace shown here can handle one ton of compacts a day, pushing a tray load into the muffle every 20 to 30 min. Each tray is loaded with about 150 pieces, the total weight of tray and charge amounting to about 60 lb. Of these, 12 are needed for the train of trays in vestibule, heating chamber, and cooling tunnel. By passing propane gas through a "cracker" (the central box-like device in the photograph of the atmosphere plant) a protective atmosphere is produced, which, before reaching the charge, is blended with metallic lithium vapors obtained from heated lithium salts.....The charge is heated to the correct temperature (ranging between 2000 and 2200° F.) and kept for 30 min. to 2 hr., depending on its nature and the required properties. It is then cooled to room temperature in extension chambers clearly shown in the view below, also filled with the protective atmosphere. Discharge of a tray must precede charging of a new one for reasons of space; a tray is pulled manually through a flame curtain which protects the furnace muffles from cross surges of outside air.....Thus treated, the metal is strong and plastic, capable of sustaining severe cold deformation without failing.

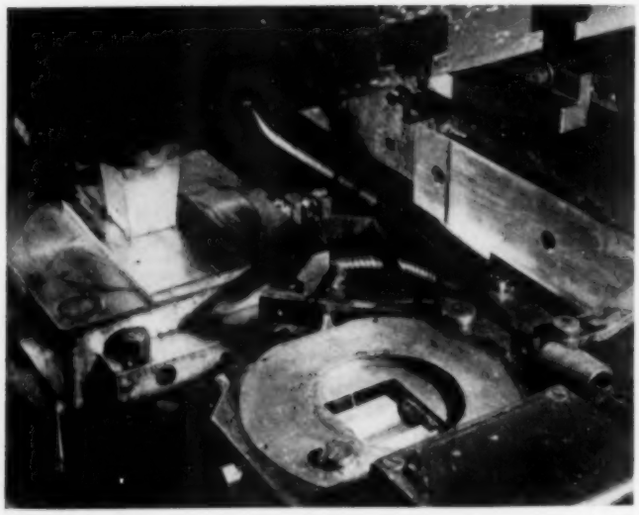


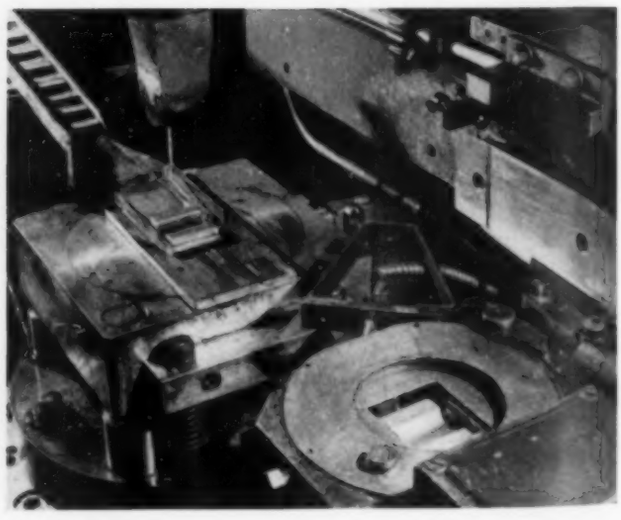
Full Automatic Coining





The sintered ferrous metal parts are finally condensed in a coining die whose cavity and punches are made to the exact dimensions of the finished piece. Like the molding operation, coining can be carried out in a fully automatic cycle. Inserting a sintered compact into a receptacle is the sole operation to be done by hand (top left). The receptacle is part of a moving slide, which carries the piece over the die; reaching that point the compact drops into the cavity. This is shown in the second view. While the carriage retreats, the ram of the press moves downwards, and the punch enters the die as photographed below (left), exerting the necessary pressure. After the pressure is released, a knockout ram ejects the piece from the die. The advancing carriage containing a new piece pushes the coined piece ahead onto a slide or conveyer, and a new cycle starts.

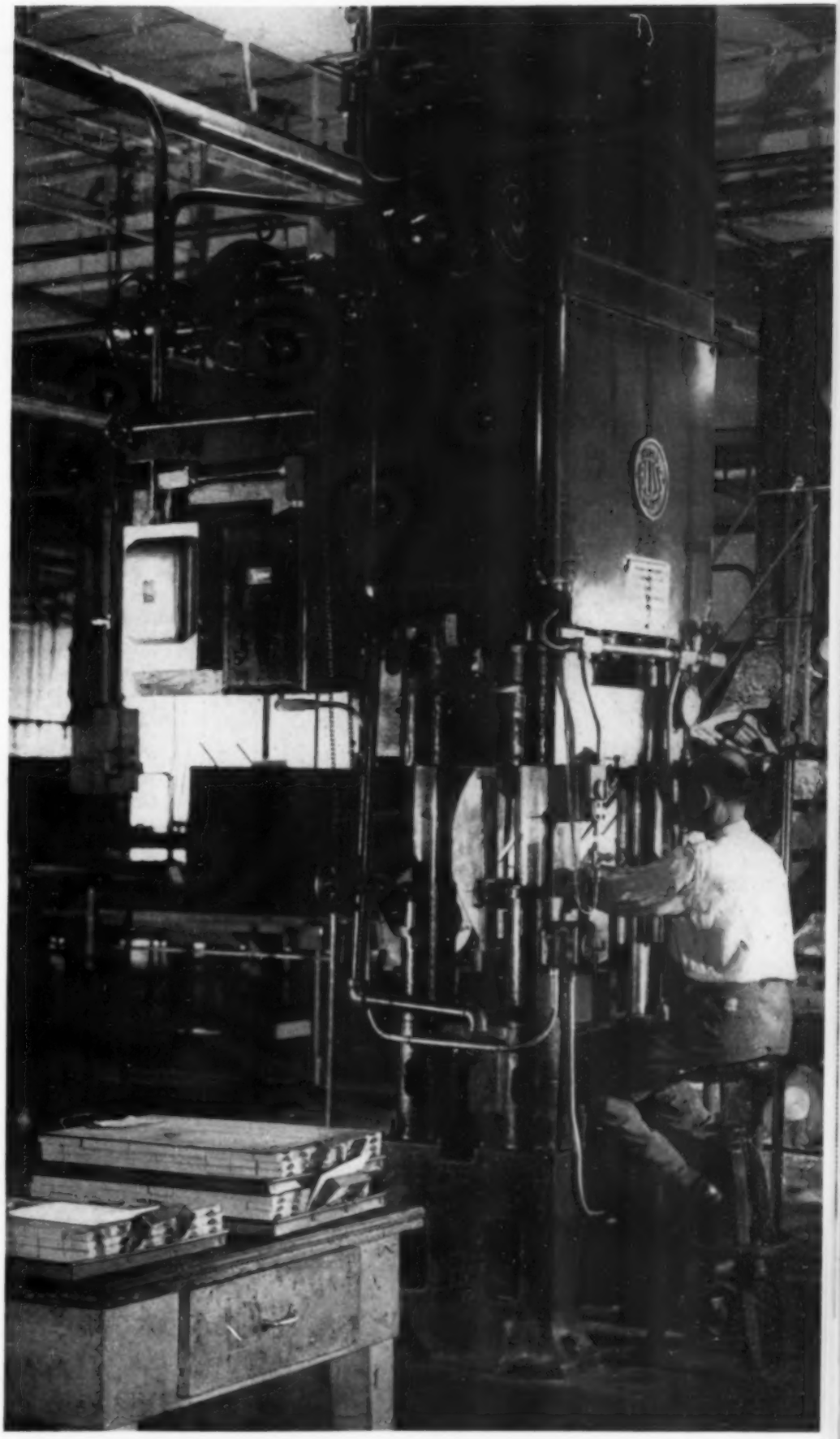




Pressures as high as 100 tons per sq.in. are sometimes necessary to produce dense parts of high physical properties. Modern hydraulic presses are yielding sufficient pressure for coining compacts up to 10 sq.in. in cross-section. Their production rate, limited to four to six pieces per minute,

if the parts are placed in the die by hand, may be increased to about ten pieces per minute if the compacts are fed into the die automatically, as indicated on page 546. To permit coining of pieces of more uniform density throughout the cross-section, the die is built on a floating base and pressure is obtained from two opposite directions in a single-action type of press, such as photographed on this page. (In this illustration the feeding is done by hand.).....Proper lubrication is very important for a long life of the die. Although refinishing of worn-out die liners and punches generally becomes necessary when production exceeds 100,000 to 200,000 pieces, replacements may not become necessary before the million mark is reached.

The coined parts are often still in need of a final heat treatment. This may be an annealing treatment to relieve the stresses caused by the cold deformation during coining; it may be a surface hardening or through hardening treatment; or it may be a surface treatment to make the parts corrosion resistant. Tray loads of parts, while surrounded by a protective atmosphere, are again automatically moved through furnaces such as previously shown....Finally, the parts are finished by deburring, sanding, straightening, or other necessary manipulations. After test pieces have been gaged and selected for physical laboratory control, the parts, if not previously rendered corrosion resistant, are coated with a thin oil film to prevent rusting. Products are then ready for packing and shipping.



Magnesium

Industrial Significance of the Basic Characteristics of Magnesium*

By J. D. Hanawalt
Director, Metallurgical Dept., Dow Chemical Co., Midland, Mich.

THE ENGINEER'S ability to improve his product and reduce costs depends upon his knowledge of design and his knowledge of materials and their processing. Therefore, it is to his advantage to understand the basic characteristics of magnesium. Probably for each metal there exist types of uses for which it is best or particularly fitted and, in time, when full information is available, engineers will know clearly what these are. But full and true information about magnesium has not been easy to acquire because the production, alloying and uses of this metal are in a period of rapid growth. In such a period, not only our ideas about facts, but the facts themselves change frequently. Metallurgical development has mainly taken place in the last 25 years. We have been coming through a period in which misinformation about magnesium has been almost as prevalent as correct information, and it is time to review the facts and sweep away the false ideas.

In this modern world of technology the development of a material initially consists almost wholly of fundamental research into its nature and properties and the problems of producing its various forms. Beyond a certain point, however, these methods of attack result in a much slower rate of advance unless the material is put into actual use. Actual usage gives data never obtained in the laboratory and serves to direct further research. After this "pilot plant" stage comes the third stage, which is the period of widespread acceptance and understanding of the facts by engineers and industry, and their utilization in commercial design and mass production.

Somewhere in the transition between the second and third stages is where magnesium stands today. So the forward looking engineer should be interested in an analysis of the situation and he is entitled to a truer picture than he may have received from hearing so much about the "growing pains" of the metal.

*The first portion of a paper presented before the Engineering Society of Detroit, Jan. 4, 1946.

German Magnesium Industry

There are some interesting things about the German magnesium industry which I learned during an investigation over there last summer. Here also is a good example of the difficulty of arriving at the truth.

It has been very commonly thought and stated in the United States that magnesium is a metal with which Germany is richly endowed, and that Germans used magnesium much more extensively than we did because they did not have enough of other metals — in other words, that the magnesium industry in Germany was operating under some very special and artificial economy. Quite the opposite is true.

In Germany, magnesium had to face strong competition from all other metals, particularly from a highly developed aluminum industry, and consequently magnesium was used only when it was the best material for the purpose. In the years 1930 to 1940, Germany not only produced proportionately more primary aluminum ingot than did the United States, but more in absolute amount; some years considerably more. For example, in 1935 German production of aluminum amounted to 69,000 tons, while United States production was 59,000. Magnesium production in Germany was about one-tenth that of aluminum.

Germany's main production of magnesium was from dolomite, which is a common rock in practically every country. Germany is really closer to large bauxite sources needed for making aluminum than is the United States. As a matter of fact, Germany, because of her lack of electric power, could hardly be called a "natural" country

for either aluminum or magnesium. That there are no natural advantages in Germany for producing magnesium is borne out by the fact that the great proportion of Germany's wartime magnesium expansion was done *outside* of Germany, in Norway and in Austria. Germany's wartime-planned capacity outside Germany equaled her internal capacity. In explaining their severe shortage, German engineers painfully related that their plant in Norway was bombed flat the day it began production, and the two plants in Austria were bombed before completion.

The idea that magnesium is a "German metal" is one which was put out by the I. G. Farbenindustrie, the original large producers, as a clever promotional scheme to help sell their metal to the German people in competition with the strong aluminum interests. The basis for their claim was simply that they first developed magnesium industrially.

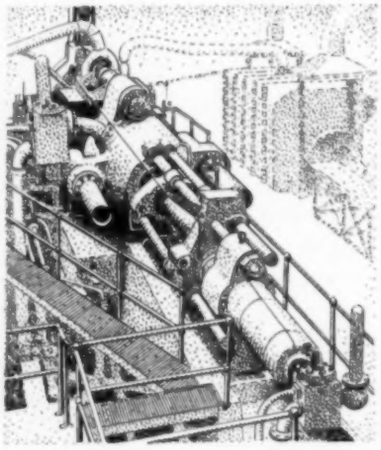
My personal evaluation of the German magnesium industry, which I believe agrees with that of the other American observers, was that the Germans were somewhat below the United States in metallurgical development and processing techniques, with a few specific exceptions such as in die casting and forging. However, due to their earlier introduction of magnesium industrially and their more extensive exploitation of its inherent characteristics, they had big advantages in design experience and a variety of service experience.

For example, they made their first successful application to textile machinery in 1921, and by 1938 were using 300,000 lb. of magnesium every month in the textile industry alone — which is more than the United States was fabricating in *all* forms at that time. They made considerable use of magnesium for wheels and for engine and transmission housings on trucks and busses. Practically all passenger cars used a magnesium oil pump (which was cost-competitive because of an economical combination of die casting and machining). Fans, pulleys and other parts of cars were also of magnesium. Forgings, large and small, were in use in German aircraft; an especially impressive example is shown in Fig. 1, a photograph of a very large one used for cannon-mounts. The German army also used many cast magnesium artillery wheels, some 5 ft. in diameter. Aircraft engine

Fig. 1 — Magnesium Parts Made in Germany. Sand cast aircraft engine crankcase, die cast automotive fan, forged cannon-mount

crankcases of cast magnesium were made in quantity for engines up to 700 hp., and had passed acceptance tests for a 1400-hp. engine. The *Volkswagon*, or people's car, had a magnesium crankcase, transmission housing and blower.

The utilization of magnesium before the start of the war in Germany was roughly 30% in ordnance, 40% in aircraft of all kinds, and 30% in industrial and commercial uses. At the start of the war, 95% of magnesium production was allocated to the air forces, and most other applications (even such as the radio housings men carried on their backs) were ordered to be converted to aluminum or zinc because of the shortage of magnesium.



I shall not further discuss German magnesium, but I would like to emphasize the fine progress made there in the face of a large aluminum industry and with the same metallurgy and process technology and relative price situation as existed in the United States. They simply made good application of magnesium's inherent characteristics and used the metal not only where it was cost-competitive, but primarily where weight saving was worth a reasonable premium.

Process Economics

Now I want to discuss the subject of the economics of magnesium as broadly and basically as possible. It has been commonly considered that magnesium is expensive and difficult to fabricate. Such an idea did not originate from nowhere, and if one remembers only certain figures and past difficulties, this idea seems an easy conclusion. However, this would be a false lead and the truer answer is more involved and harder to get.

The first striking fact about the economics of magnesium is that it is potentially the world's most universally available and widely distributed metal. While iron and aluminum form a somewhat larger percentage of the earth's crust, magnesium is more abundant in high grade ores which are widely distributed among the various countries. In addition, magnesium exists in the sea to the extent of ten billion pounds in each cubic mile of sea water. When the Dow Chemical Co. successfully recovered magnesium from sea water at their Texas plant, in a large scale commercial operation, it tapped this infinite reservoir of magnesium which is available to almost every country in the world. Sea water is a source of unchanging composition. All of the magnesium made in the world to date could have been taken from about one-tenth of a cubic mile of sea water! A tubful of sea water would contain about 1 lb. of magnesium in the form of magnesium chloride.

The significance of the fact that we are depleting no limited resources when we make magnesium has probably not yet been fully realized. Magnesium has been produced commercially by a number of different processes, all involving comparatively simple operations and power requirements which are not excessive. Magnesium is already cheaper per unit volume than any other structural metal except iron.

In alloying and casting molten magnesium into ingots or shapes, one must prevent the metal from burning. This causes an extra expense in the form of melt loss and special fluxes and agents. However, these extra costs will become less as developments continue. There was a time not so many years ago when — because of burning — magnesium could not be cast into green sand molds at all. Then, accidentally, the great effectiveness of sulphur as an inhibitor was discovered. All of the important agents used today have been discovered in the last 25 years, and future developments can be expected to make magnesium easier and easier to handle.

In the meantime, the special requirements may even be offset by other properties if advantage is taken of them. For example, it is only recently that its low melting point and inertness toward iron have been utilized to economic advantage by the scheme of pumping molten magnesium like an ordinary liquid through iron pumps and pipes. The possibilities of closed iron equipment and of automatic machine casting have not yet been fully exploited, though there is much activity in these directions. Other developments in the cast-house and foundry are direct spectrochemical control of alloy composition and reverberatory furnace melting, both of which were introduced during the war years.

Progress in the processing of wrought magnesium during the war years has been equally assuring, and substantiates my contention that magnesium can be put into large scale operations, whereupon costs become competitive with other metals on the same scale of operation. For example, rocket launcher tubing of 4½-in. diameter

was extruded on a 5000-ton press at rates of 80 ft. per min. Metallurgists in this country, as well as in Germany, are stating that magnesium is less difficult to forge in complicated shapes than aluminum, and that they can always forge it in the same or fewer steps than would be required for aluminum.

The fact that magnesium has limited cold workability has been emphasized so much that the advantages of its superior hot workability in forming and drawing are only beginning to be appreciated. There are examples of single deep draws (of 60 to 70%) in magnesium that would require two or more steps in aluminum or steel. (See Fig. 2.) All that is required is know-how and a superheat of a few hundred degrees — not an expensive operation, since the equipment and technique for temperature control have been developed.

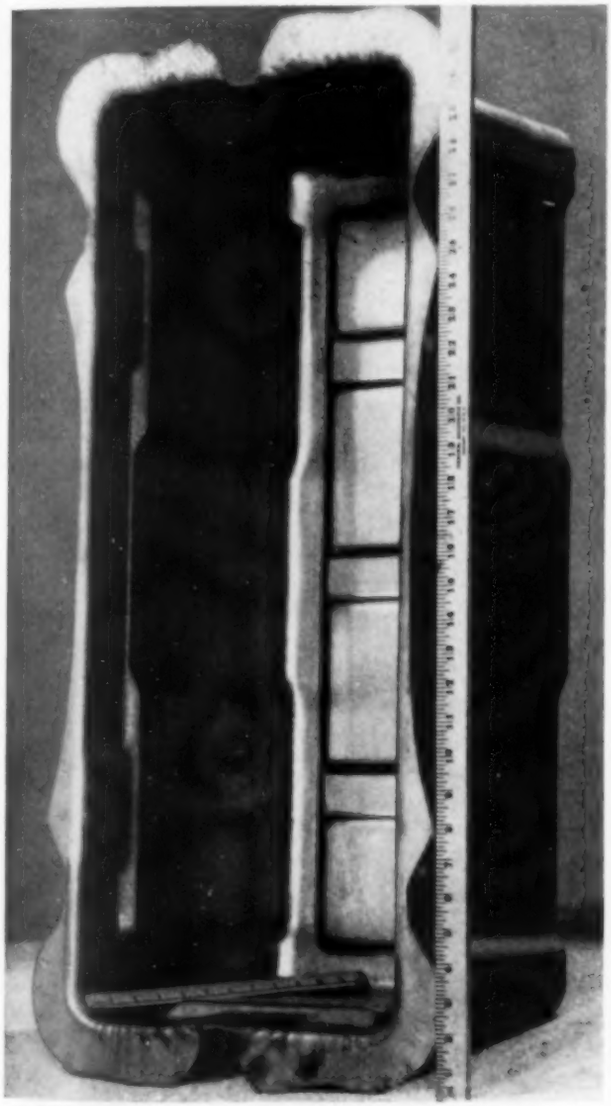


Fig. 2 — Box, Made of Magnesium Alloy, Deep Drawn From Hot Sheet in a Single Operation

More and more new fabricators are showing they can do things with magnesium formerly assumed to be impossible. Within the last month a large aircraft manufacturer has shown that it is commercially feasible to form magnesium sheet on a drop hammer instead of a press, and at a great saving in die costs when producing only a limited number of parts. With the introduction of temperature control, such techniques of spinning and roll-forming — well known for other metals — are working out to advantage with magnesium. Welding, whether gas or electric, can be very efficiently done.

Machinability is frequently an important consideration. Figures on such things as cutting speeds, power requirements, tool life, and surface finish show that magnesium can be named "the most machinable of metals". A large manufacturer of aircraft landing wheels states that just twice as large a machine shop would be required to produce the wheels in aluminum as to produce them in magnesium.

Very recently the chief engineer of a large firm made the remark that he preferred magnesium in the shop because it was so workable. (During the war his firm had used 20,000,000 die castings, 65% of which were of magnesium.) Another United States concern with wide experience lists machining costs as 25% higher for aluminum castings, 35% higher for bronze castings, and 50% higher for cast iron than for magnesium castings.

In Germany the Opel Automobile Co.'s engineers stated that the machinability of magnesium was so good they could not take full advantage of it with their standard machine tools. During the war they substituted other metals on a number of aircraft parts, and their data showed about five times as many man-hours for machining iron as for a magnesium part.

At the *Volkswagon* plant, special high speed equipment had been installed for machining magnesium parts. The original automobile had a magnesium crankcase, gear box (transmission housing), oil pump, cooling air impeller, and miscellaneous cover plates. In 1941, the government ordered these parts changed to iron, but rescinded the order when production could not be maintained. Later in 1943, when the magnesium shortage was really serious, the parts were all changed to aluminum. Using their special machines, *Volkswagon* engineers reported they found it required 2 hr. to finish the same parts in aluminum which had required 1 hr. in magnesium.

Combinations of favorable processing steps

may sometimes make a magnesium article entirely cost-competitive — as, for example, the German automobile oil pumps of die cast and machined magnesium, or the die cast generator and starter end plates on the pre-war Ford cars. The facts that casting is the most direct form of fabrication from the ingot to the finished article, and that magnesium may be handled in automatic iron casting (permanent mold) equipment, combined with the fact that cast magnesium alloys have such good and serviceable mechanical properties, puts a great emphasis on the products of the foundry industry. Pulleys, aerodynamically efficient fans, and many other simple symmetrical shapes in the motor car should lend themselves ideally to this technique.

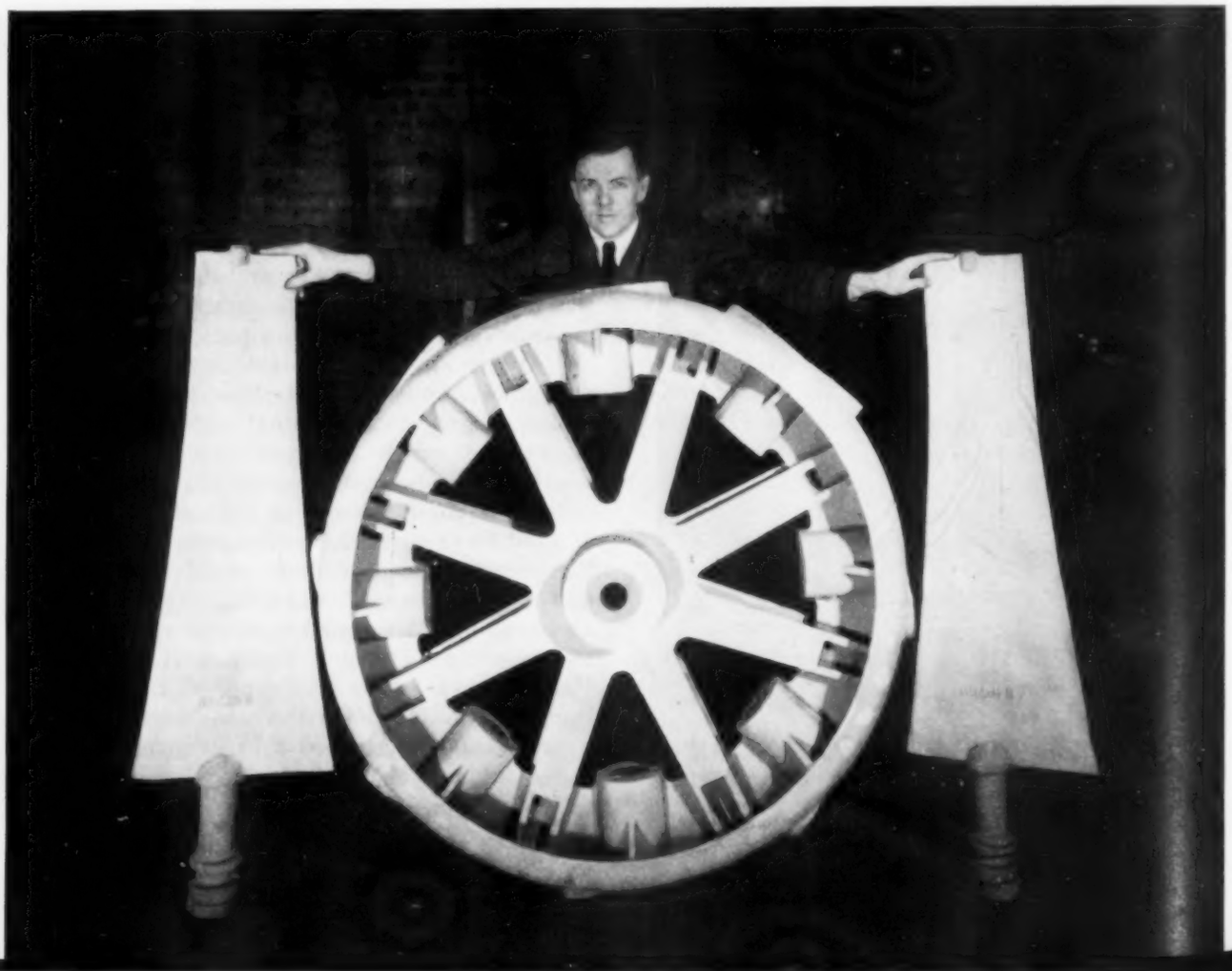
With increasing experience in the hands of more people, new economic advantages in processing steps are being uncovered and the previous difficulties are being minimized.

The various aspects of the economics of processing magnesium have been discussed at some length because it is important to realize that the cost of a magnesium part in the past does not determine its cost in the future. The developments which have been cited (such as reverberatory melting, alloy composition, temperature-controlled processes, and so on) remind one very much of the long series of developments in the iron and steel industry. Here the price came down cent-by-cent as blast furnaces became bigger and more efficient and new methods became available for the control of carbon, sulphur and other elements. Technical developments and consumer volume grew side by side.

There is no evidence that the difficulties faced by the magnesium industry are any greater than those faced and overcome by the steel industry. In fact, one is tempted to think that if the positions of steel and magnesium had been reversed and someone had suggested that steel articles could be made cost-competitive with magnesium after the latter had had the advantage of 50 years of commercial development and usage, he would be considered as overly optimistic. One would think of the white-hot melting temperature, and of the refractory problems, and of the personnel hazard, and of the high density, and the expensive handling equipment. One would look at the rusting problem and the cost of keeping the steel painted. One would contrast these with the low melting point and light weight of magnesium and conclude that steel would never be cheap enough to compete in any place where magnesium would do!

These latter arguments are admittedly fanciful at this time, but there are still many practical considerations in the immediate present.

Fig. 3 — Dowmetal Sand Cast Fan Hub and Blades



● The widespread use of triple-alloy steels containing Nickel, chromium and molybdenum is based on extensive experience in widely divergent engineering fields.

It has been found that they can be counted on for consistent performance. The depth to which full hardness is developed is comparable to that attained by other alloy steels. Their response to heat treatment is dependably uniform.

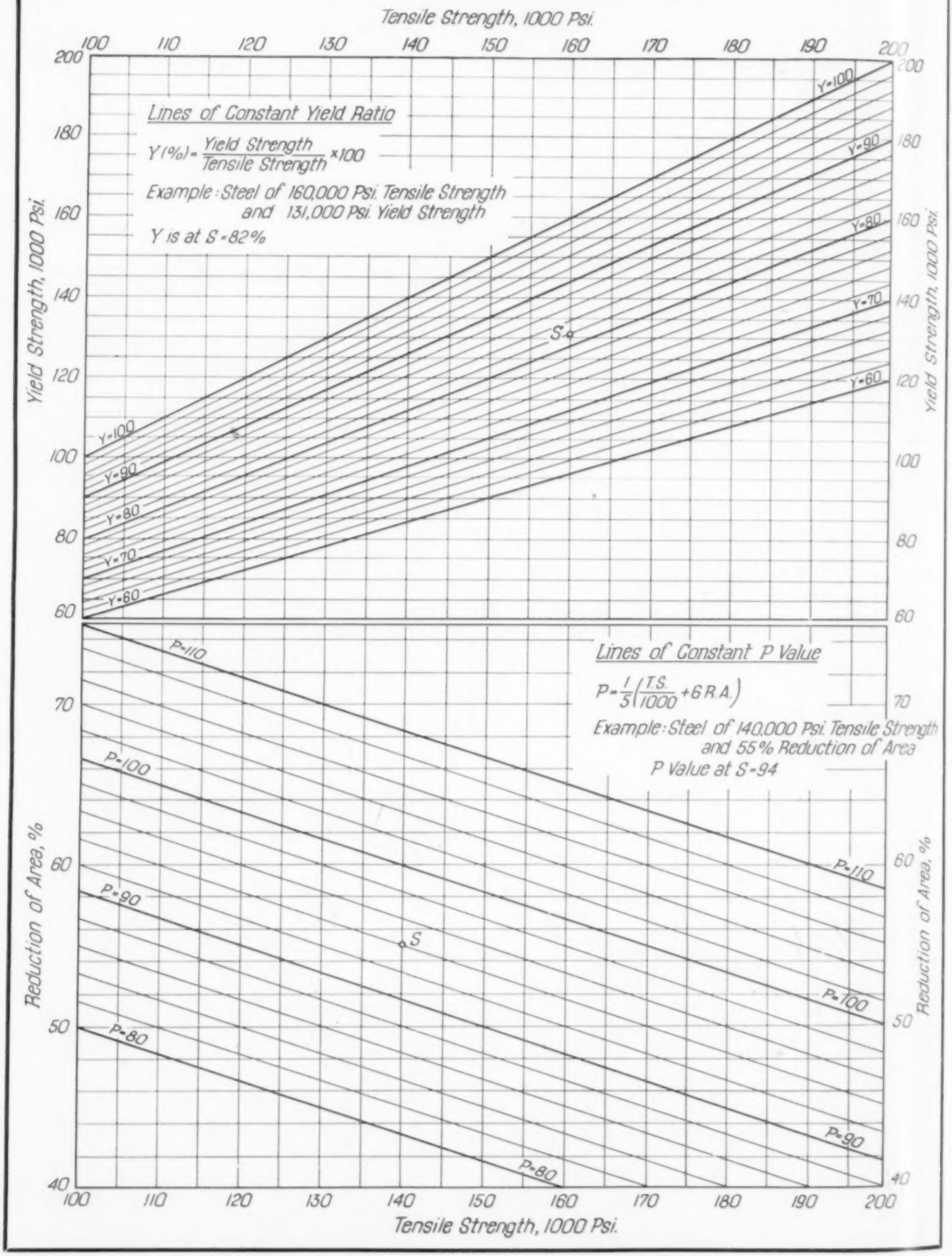
Moreover, the wide range of compositions available, makes it possible to select *accurately* suitable alloy steels for a broad range of applications.

Inquiries regarding the selection and uses of triple-alloy steels containing Nickel are invited.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 Wall Street New York 5, N. Y.

Diagram for Yield Ratio and P Value

By Roger F. Mather, Chief Metallurgist, Willys-Overland Motors, Inc.


Tensile Strength, 1000 Psi.
Yield Strength, 1000 Psi.
Lines of Constant Yield Ratio
Y(%) = Yield Strength / Tensile Strength x 100
Example: Steel of 160,000 Psi. Tensile Strength and 131,000 Psi. Yield Strength
Y is at S = 82%
Y=100
Y=90
Y=80
Y=70
Y=60
S
Lines of Constant P Value
P = 1/3 (T.S./1000 + 6 R.A.)
Example: Steel of 140,000 Psi. Tensile Strength and 55% Reduction of Area
P Value at S = 94
P=110
P=100
P=90
P=80
Reduction of Area, %

New Developments in the Study of Surface Chemistry

By Earl A. Gulbransen
Research Chemist, Westinghouse Electric Corp., East Pittsburgh, Pa.

THE STUDY of surface chemistry has long been handicapped by the lack of instruments. This is due to the fact that the nature and structure of an infinitesimal surface layer of atoms has such an important effect on the phenomena involved. However, during the past decade three instruments have been developed to a point where they may aid the scientist's quest. These are the electron microscope, the electron diffraction camera and the vacuum microbalance. But before considering each instrument in detail, and its own particular application, it is of interest briefly to review a few facts concerning surface chemistry.

Many industrial and technical processes are based on chemical and physical reactions that take place at the very surface of the substances involved. The action of catalysts in the production of ammonia from nitrogen and hydrogen is but one of many which utilize catalytically active surfaces. The resistance of materials to corrosion, oxidation and tarnishing requires the presence of a surface film of definite characteristics. Many reactions in plant and animal life are also intimately connected with the existence of surface films and surface reactions. In fact, one cannot escape the conclusion that surface chemistry is fundamental to life as well as to technology.

The importance of the surface layer can be realized if it is thought of as the boundary zone between different states of matter. For example, a chemical reaction between a solid and a gas must occur through such a boundary zone. This zone also has many unique physical properties because of the unbalanced nature of the forces acting on the surface atoms. Unbalanced interatomic forces may explain the physical and chemical adsorption of gases and liquids on solids and, in addition, the ease with which the surface layer of a metal reacts with its surroundings to form surface oxides, or other compounds.

Three fundamental factors are involved in relating the properties of a given surface to any practical problem. These three factors are *(a)* the physical form of the surface, *(b)* the chemical nature of the surface layer and *(c)* the velocity at which chemical and physical changes occur on or through the surface. It is to the study of these three factors that the electron microscope, electron diffraction camera and the vacuum microbalance are being applied.

The Electron Microscope — For many years the unaided eye and the light microscope have been used to study the physical form of solids. The correlation of these observations with the physical properties of metals and alloys has developed the science of metallography, whose usefulness has been proven beyond doubt by the present state of our metals technology. However, the study is as yet far from complete. New techniques and new interpretations are constantly being developed.

One of these new techniques arose from the electron microscope. The useful magnification of the ordinary light microscope is limited to perhaps 2000 diameters by the wave length of light and by the numerical aperture of the lens system. The very small depth of focus is also an important factor limiting the use of this instrument when studying rough surfaces. Only by the use of special equipment and ultra-violet light is it possible for the expert metallographist to push this limit up to 5000 diameters.* The electron microscope, on the other hand, has a useful magnification of 20,000 to 50,000 diameters, as well as a

*See "On the Design and Construction of a Precision High Power Metallographic Apparatus", by Francis F. Lucas, *Transactions*, A.S.S.T., 1933, p. 1112.

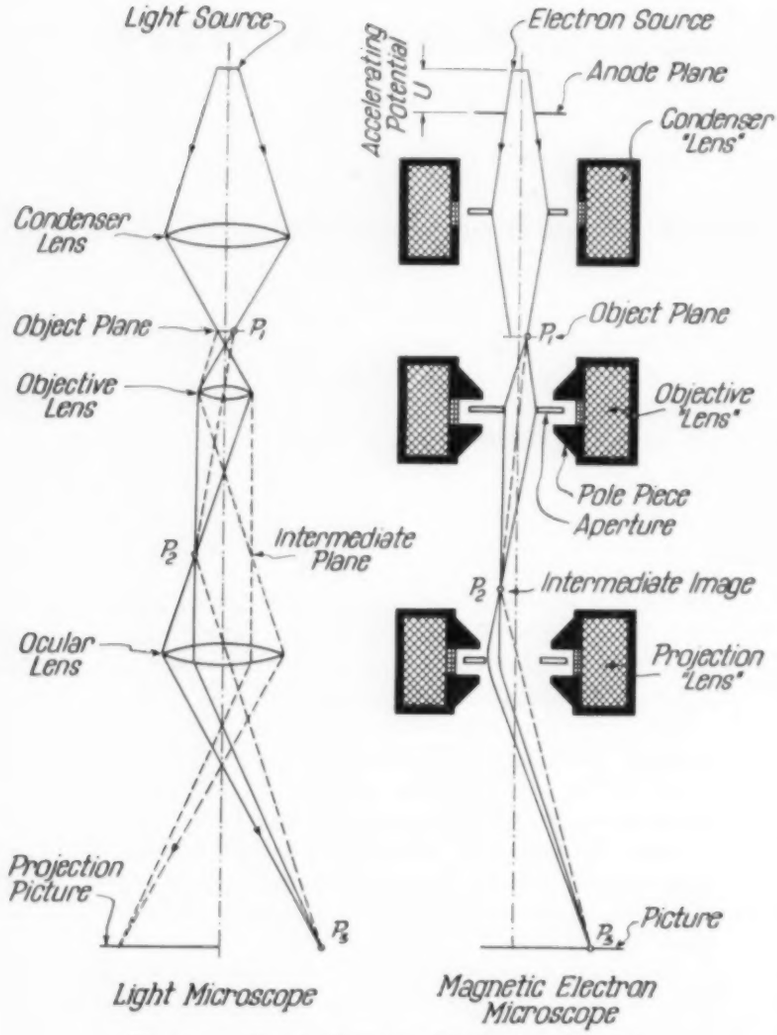


Fig. 1 — Sketch Showing Similarity of Optical Systems of Transmission Microscopes for Light Waves and for High Energy Electrons

comparatively large depth of focus. This increase in useful magnification over the light microscope is due to the use of a homogeneous beam of high energy electrons of 30,000 to 60,000 volts. These electrons when in motion have associated with them a train of waves whose length is about one hundred thousandth that of a light wave. Since the numerical apertures are small (0.002), the overall gain in magnification is 20 to 50-fold in commercial models available at the present time.

The optics of the electron microscope are similar to those of the light microscope. However, instead of glass lenses, the electron microscope uses certain types of magnetic and electrostatic fields which serve the same essential purposes of focusing. These elementary facts are shown in Fig. 1, above.

Due to the fact that electrons are charged particles they are scattered readily by matter. Therefore the microscope must be highly evacuated and the specimens observed in the vacuum system. These specimens must be extremely thin or, if small particles are to be studied, they must be supported on a thin plastic film permeable to the electron beam. This plastic film is supported by a 200-mesh metal screen.

For materials opaque to the electrons only a shadowgraph is obtainable. A typical micrograph of this type is shown in Fig. 2, which records, at 5000 diameters, the size and size distribution as well as the shape of the molybdenum powder particles used in powder metallurgy. (The length of a micron — 0.001 mm. — is shown at the right of the photograph.)

If the materials are only partially opaque to the electrons, the structure itself can be studied. This would be the case in many biological specimens.

In order to study the structure of the surface, the layer must either be removed in the form of a thin film or a transparent replica of the surface must be made. If the surface consists of an oxide film, it can be removed either by chemical or electrochemical methods. If its structure is to be studied, the film must be less than a few hundred Ångströms thick.* Figure 3, at the bottom of the next page, shows a micrograph at 30,000 magnification of the oxide layer formed on a piece of aluminum after oxidation at 500° C. for 5 min. in 0.1 atmosphere of oxygen and then removed electrochemically. Studies of such pictures are very interesting from the point of view of oxidation resistance of metals.

Surface Replica Technique

If opaque materials are to be studied, special replica techniques transfer the structure of the surface to a thin film which gives a reasonable approximation of the original surface.

A rapid and relatively simple technique is the "one-step formvar" replica. A dilute solution of formvar in dioxane or other organic solvent is allowed to flow over the surface. Upon evaporating the solvent, a thin film of formvar is formed on the surface. This film is carefully separated from the metal, placed on a metal screen and then put into the microscope for study. Unfortunately, this simple process gives only a rough approximation of the original surface.

A much more successful replica technique is the polystyrene-silica process developed by R. D.

*1 Ångström unit (1 Å) equals 0.0001 micron or 10^{-7} mm. The wave length of blue light is on the order of 5000 Å. The waves associated with a stream of 50,000-volt electrons are on the order of 0.05 Å.

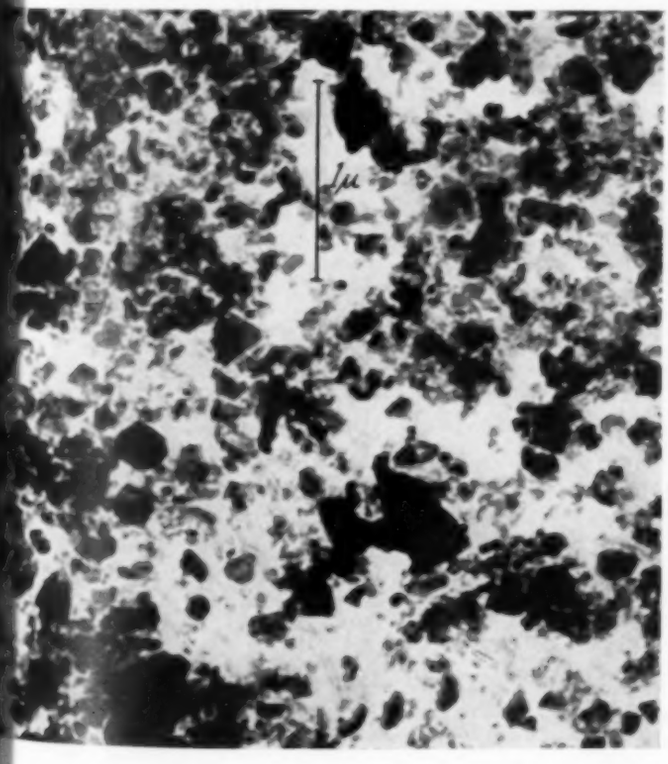
Heidenreich. This is a two-step process. Polystyrene is first molded around the metal or other surface at a temperature of 160° C. and 3000-psi. pressure. Under these conditions the polystyrene forms a good replica of the original surface. After cooling, the metal is separated by cracking or by selective chemical action. A thin film of silica is now evaporated in a vacuum over the polystyrene surface. The surface is again accurately reproduced in the silica film. This film is in turn separated from the polystyrene by dissolving the polystyrene in ethyl bromide. Small sections of the film are then mounted on metal screens and placed in the microscope for study. Four such replicas are shown in Fig. 4 and 5 on the next page.

Figure 4 shows polystyrene-silica replicas (at 5000 magnification) of the surface of two pieces of polished and etched copper. The one at the left shows the rectangular twinning bands (or the block slippage) which intersect the surface layer and are caused by slight cold working during processing. The effect of heating at high temperatures to remove residual internal stresses is shown at the right. No evidence of slip bands is noticed; the fine structure is due to selective attack by the etching solution.

Figure 5 shows at 11,000 magnification some effects of oxidizing the surface of polished and etched pure magnesium. The structure before oxidation is shown at the left while the one at right shows conditions after oxidation at 500° C. for 120 min. at 0.1 atmosphere of oxygen. The oxidized surface appears to be smoother and of different structure from the original surface, as might reasonably be expected.

Fig. 2 — Particles of a Molybdenum Powder, Opaque to the Electron Stream, Form a Shadow Image. Magnification: 5000 diameters

Fig. 3 — Electron Micrograph at 30,000 Diameters, of Oxide Film Stripped From Aluminum



These few examples show that the electron microscope has a very important role to play in studying the physical features of the surface. These features include not only the surface roughness but also the presence of cracks, voids, inclusions and stress residuals.

Electron Diffraction — The development of electron diffraction analysis as a tool for the study of surface chemistry arose from the prediction by De Broglie in 1924 that a wave system is associated with particles in motion. According to this prediction the wave length λ of the associated wave train is given by the equation $\lambda = \frac{h}{mv}$. Here v is the velocity of the electron, m the mass and h is Planck's constant. This prediction led to a series of experiments to prove that a homogeneous beam of electrons could be diffracted by a grating formed by the atoms of a crystal. The success of these experiments led to the development of a method for identifying the atomic grating (determining the arrangement of atoms in a space lattice) by correlating wave length of the electrons with the

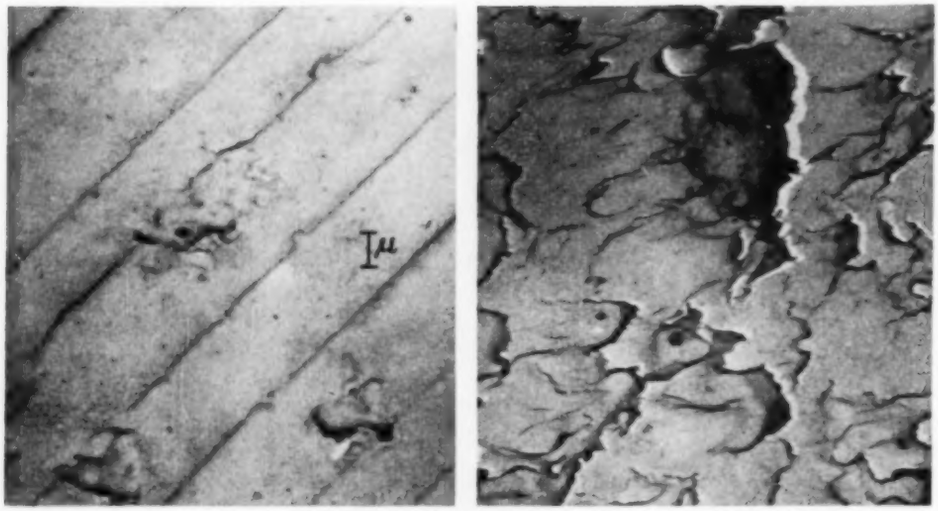


Fig. 4 — Electron Micrographs (at 5000 Diameters) of Polystyrene-Silica Replicas of Copper Surface Slightly Worked (Left) and Annealed (at Right)

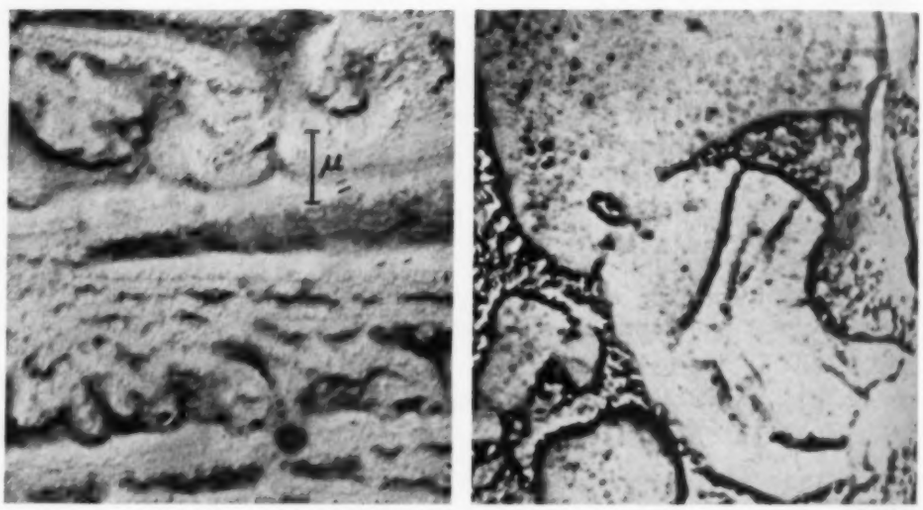


Fig. 5 — Electron Micrographs (at 11,000 Diameters) of Polystyrene-Silica Replicas of Magnesium Surface Polished and Etched (Left) and Oxidized (Right)

location and intensity of the diffracted beams.

An important milestone in this development was the discovery in 1930 that electrons impinging at near-grazing angles on plane surfaces would give diffraction rings characteristic of the surface material itself. This technique of electron diffraction is called the reflection method.

Thin specimens of matter (or small fragments or powders) can be studied directly by passing the beam of electrons through the material and observing the diffraction pattern on a fluorescent screen or photographic film. This earlier technique is called the transmission method, and its results give a statistical view of the material, as though it were viewed — or penetrated — from all possible angles.

Since the scattering of electrons in matter is very high, the penetrating power of the electrons is extremely small. Therefore, the reflection method must be used to study opaque metal surfaces. In this method only the first few atomic layers are effective. Thus a new method is now available for studying the boundary layer so important in the chemistry of metal surfaces.

The electron diffraction camera in use at the Westinghouse laboratories is shown schematically and photographically in Fig. 6. The apparatus consists essentially of a source of homogeneous high voltage electrons of 30,000 to 60,000 volts energy, a magnetic focusing coil, a sample holder and manipulator, a camera section, and a device for maintaining a vacuum. The camera includes a fluorescent screen by which the electron pattern can be made visible and a photographic film which permanently records it. To reduce the scattering of electrons the apparatus is continuously evacuated by a series of pumps to a very low pressure.

To obtain a good pattern by the reflection technique the samples must be plane, crystalline and somewhat abraded. The surface preparation is important. Usually the specimens are abraded flat with various grades of polishing paper, using benzene as a lubricant. Care must be taken to prevent external contamination of the surface.

If it is necessary to study the behavior of the specimens at high temperatures, they can be mounted in a furnace and studied in any gas atmosphere and at the temperature of interest. This scheme is useful for corrosion studies.

For this summary it is unnecessary to dwell upon the analysis of reflection patterns. Suffice

it to say that the dominant crystalline planes in the polycrystalline specimen diffract electrons from the incident beam, each plane forming a cone of rays with characteristic apex angle. The undiffracted beam strikes the film at the common axis of these cones and the cones themselves intersect the film in a series of concentric circles. By simple geometry relating the wave length, distance from specimen to film, and conical angle, the lattice spacing effective in producing the diffraction can be computed. From measurements of the radii of the diffraction rings it is possible to identify the crystalline architecture of the surface material.

Figure 7 shows the patterns obtained when pure electrolytic iron is oxidized at 400° C. in 0.1-atmosphere of air. The effect of heat treatment on the oxidized surface film is also shown. The left-hand pattern was obtained from the polished sample at 25° C. The pattern is not distinct although several diffraction rings characteristic of iron were observed on the original photographic film. The next pattern was taken at 400° C. in a "vacuum" before the air was added; already some oxidation has taken place and a pattern characteristic of Fe_3O_4 was obtained. Air was added up to 0.1-atmosphere pressure and

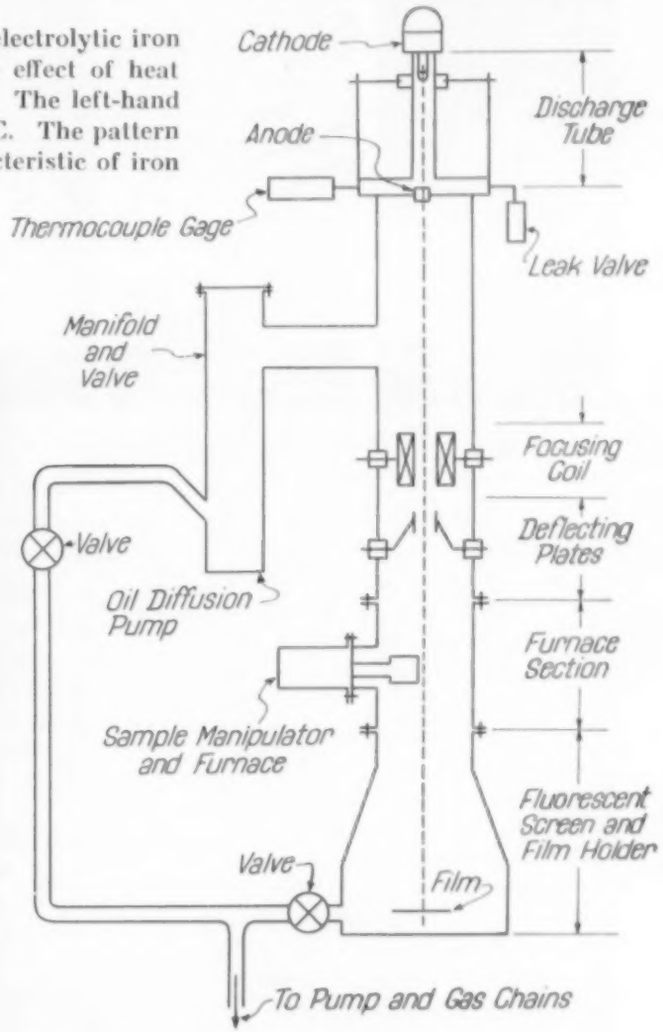
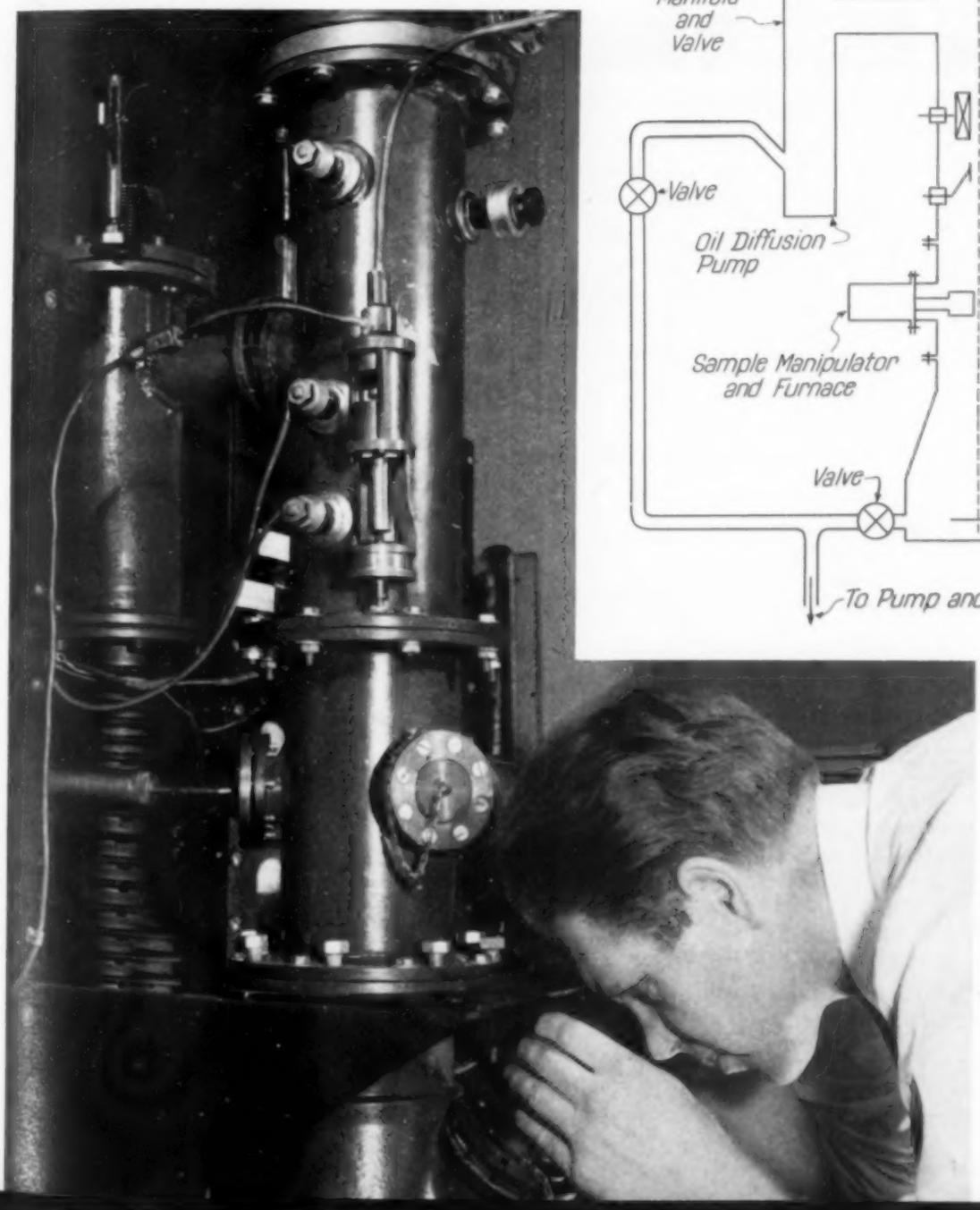


Fig. 6 — Schematic Diagram of Electron Diffraction Camera, and Photograph Showing the Author Observing the Fluorescent Screen in the Camera Section of the Instrument



Fe, polished with No. 1 grit; temperature 25° C.

Slight oxidation to Fe_3O_4 while heated to 400° C. in vacuum

Alpha Fe_2O_3 formed during 60 min. at 400° C. in 0.1-atm. of air

No change in surface oxide during 30 min. at 500° C. in vacuum

Alpha Fe_2O_3 remains unchanged after cooling overnight to 25° C.

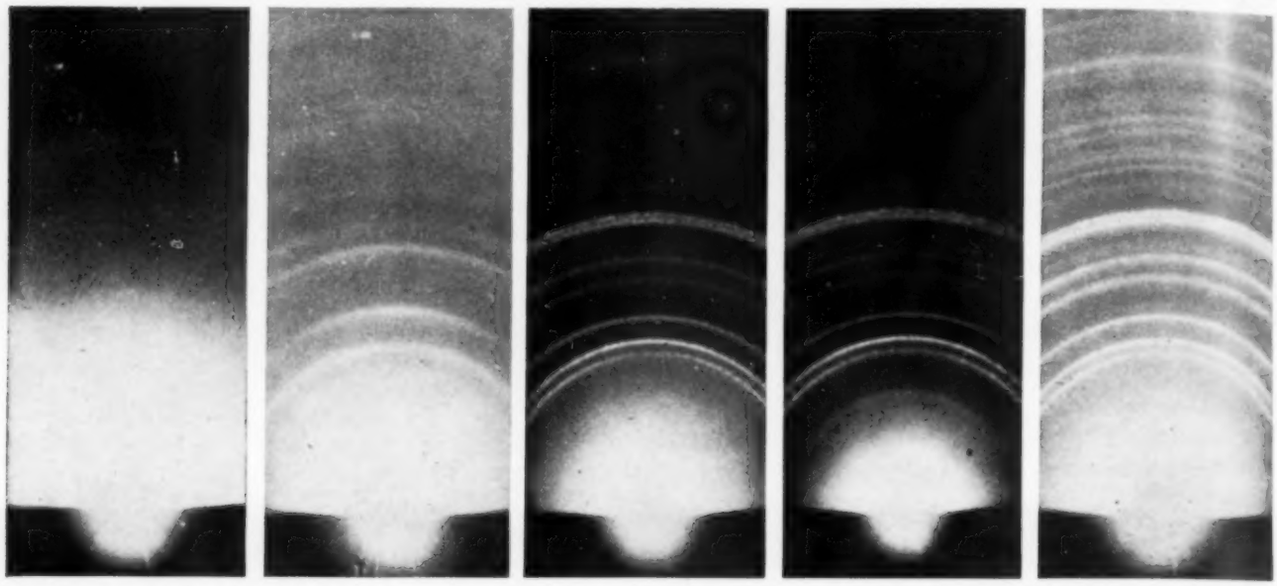
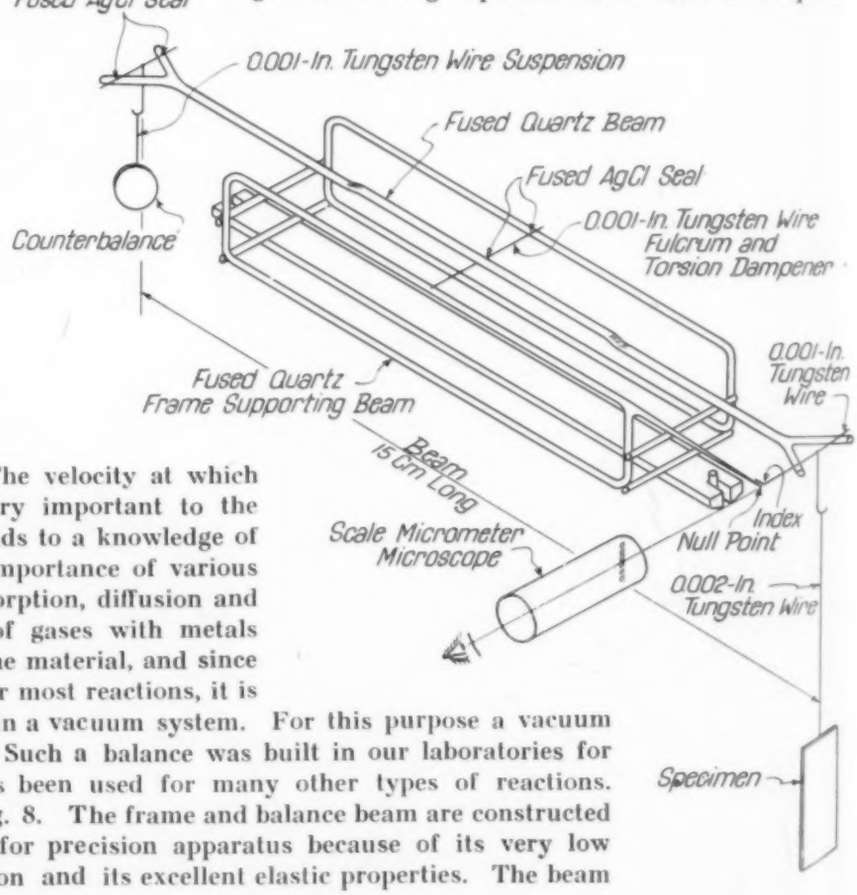


Fig. 7— Electron Diffraction Patterns From Pure Iron, Prior to and After Oxidation at 400° C.

the iron allowed to react at 400° C. for 60 min. After evacuation the pattern is found to be of the alpha modification of Fe_2O_3, as shown in the middle photograph. The effect of subsequent heating in a vacuum at 500° C. for 30 min. is shown in the next photograph; no change in the pattern is noticed. The sample was then cooled to room temperature, obtaining the last pattern. Again no change is found in the surface oxide — it is still alpha Fe_2O_3. This series of pictures therefore gives the case history of a chemical reaction occurring on the surface of a sample of iron.

Fig. 8 — Orthogonal Projection of Microbalance. Sensitivity: 1 division of scale = 1×10^{-6} g. Period: 8 sec. Beam weight: 1 g. Specimen weight: about 0.7 g. Specimen area: about 14.5 sq.cm.



The Vacuum Microbalance — The velocity at which reactions occur on surfaces is very important to the chemist. This study sometimes leads to a knowledge of how the reaction occurs and the importance of various subsidiary phenomena such as adsorption, diffusion and catalysis. Since many reactions of gases with metals involve a change in the weight of the material, and since special gas atmospheres are used for most reactions, it is necessary to carry out the reaction in a vacuum system. For this purpose a vacuum microbalance is admirably suited. Such a balance was built in our laboratories for measuring oxidation rates, and has been used for many other types of reactions.

The balance is sketched in Fig. 8. The frame and balance beam are constructed of fused quartz, an ideal material for precision apparatus because of its very low temperature coefficient of expansion and its excellent elastic properties. The beam

is symmetrical endwise and is supported by an annealed tungsten wire, 1 mil in diameter. The beam shape is chosen in order to maximize stability and minimize temperature sensitivity. Movements of the beam are observed by a micrometer microscope. The specimens used on the balance weigh from 0.5 to 1.0 g. and changes in this weight can be read to 0.00000025 g. (one quarter of a millionth of a gram). Since the balance is symmetrical and made of quartz, it has a very small pressure and temperature coefficient and has a zero point stable to a millionth of a gram over a period of several days.

The balance is enclosed in a pyrex tube as shown in Fig. 9. The auxiliary apparatus is constructed completely of glass and is directly connected to an all-glass pumping system. Pressures of one billionth of an atmosphere are readily attained. Specimens are thin metal sheets about 1 by 6 cm. and 0.1 mm. thick, and suspended by a fine wire. A furnace can readily be placed around the specimen tube and the specimens heated to any temperature up to 500 or 1000° C., depending on whether a pyrex or quartz tube contains the sample.

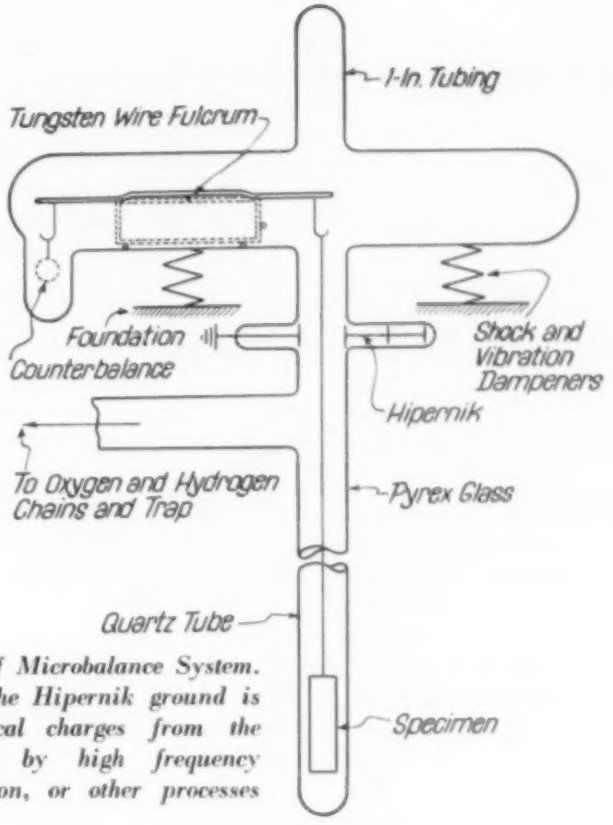
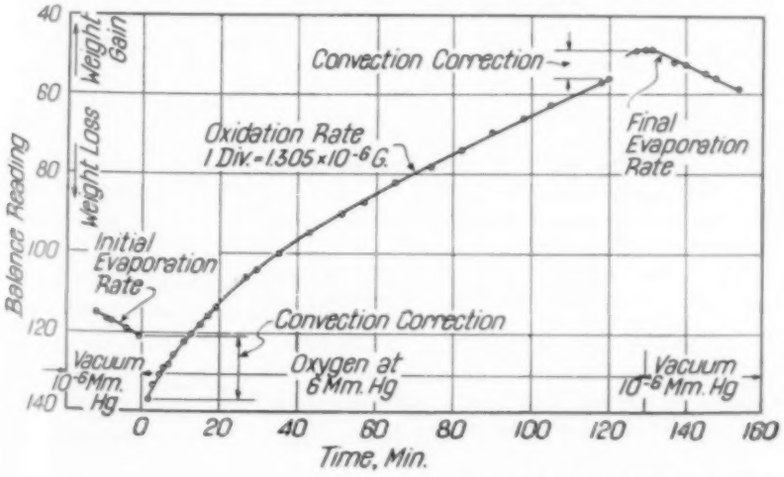


Fig. 9 — Sketch of Microbalance System. The function of the Hipernik ground is to remove electrical charges from the sample, induced by high frequency heating, evaporation, or other processes

To illustrate the use of the balance the course of the oxidation of pure aluminum at 500° C. is described in Fig. 10, where the weight-gain, expressed in millionths of a gram per square centimeter, is plotted against the time. After placing the specimen on the balance, the glass tube is closed and the system evacuated to a very low pressure (10^{-6} mm. of mercury). The furnace, controlled at 500° C., is raised around the sample and readings of the balance taken periodically. The specimen in the vacuum of the instrument is seen to lose weight at a fairly definite rate by evaporation of aluminum atoms. At time plotted as zero, oxygen is admitted to a pressure of 6 mm. of mercury. The sample gains weight (oxidizes) rapidly at first and then the rate gradually decreases as the oxide film builds up on the metal, reaching a fairly steady rate after an hour has passed. At 130 min. the system is evacuated; again the metal atoms evaporate from the surface. An analysis of the oxidation curve yields very useful information as to the nature of this important chemical reaction.

The course of the oxidation of pure magnesium at 475° C. and at 20 cm. of oxygen pressure is another typical study. The magnesium also evaporates when the specimen is heated in the vacuum. After the addition of oxygen, magnesium oxidizes in a different manner from aluminum — slowly at first and then the velocity builds up gradually to a linear rate within 3 hr. When the system is again evacuated the oxidized magnesium evaporates at a much greater rate than at first. Undoubtedly new factors must be brought in to explain the marked difference between the action of magnesium and that of aluminum. Studies of this type are typical of the problems which can be solved with this instrument.

Fig. 10 — Rate of Evaporation of Aluminum in a Vacuum at 475° C. and Its Later Oxidation in an Atmosphere of Oxygen of 6-Mm. Pressure



Correspondence

Research on Metallic Surfaces Organized in France

PARIS, FRANCE

To the Readers of METAL PROGRESS:

It would appear that the study of surface condition of metallic parts has long been neglected by metallurgists generally, despite its ever-increasing importance. Not only is this knowledge essential for predicting surface properties — friction, brightness, emissive power, chemical corrosion — but it is also of great help in assessing other properties of the part as a whole. Resistance to shock and alternating stresses (endurance), for instance, is considerably influenced by the surface condition of the part.

An event indicating the importance attributed to these problems was the creation in France in August 1942 of a "Technical Committee on the Conditions and Properties of Metallic Surfaces". Its principal functions are as follows: *(a)* To study the problems presented in the various industrial uses and applications of metals; *(b)* to define and execute research work in this field of activity, including practical tests and scientific experimentation; *(c)* to coordinate the results of these investigations and disseminate the data through France and foreign countries.

The Committee's field of activity has been subdivided as indicated in the table alongside. This classification covers both the nature of the surface and of protective coatings and also the processes used to secure protection against corrosion.

Among the problems which are currently being studied are:

1. Surface studies by micro-geometry.
2. Investigation of electrolytic deposits of hard chromium and other alloys.
3. Wear resistance.
4. Applications of electrolytic polishing.
5. Definition and measurement of adhesion of coatings such as paint and varnish.
6. Investigation of defects revealed by anodic

Program of the Technical Committees

SUBJECTS FOR STUDY OR EXPERIMENTATION	ORGANIZATION
A—1. Mechanical methods of surface finish (machining, grinding, sanding, polishing, burnishing)	Subcommittee I on Mechanical Surface Studies
2. Mechanical properties (hardness, friction, wear and physical properties such as color and polish)	
3. Geometric and physical evaluation of surfaces	
B—Chemical and physico-chemical methods of surface protection	
1. By physico-chemical modification (quenching)	Subcommittee II on Thermal Processes
2. By melting (deposition by blowpipe)	
3. By penetration (diffusion) or absorption with chemical reaction (cementation, nitriding)	
4. By application without chemical reaction or diffusion	
(a) Application by welding (overlays)	
(b) Application of an organic or mineral coating (paint, varnish, enamel)	Subcommittee III on Paints and Other Non-Metallic Coatings
(c) Application of a metallic coating by mechanical methods (as by spraying)	Subcommittee IV on Metallic Coatings
(d) Application of a metallic coating by dipping (tinning, galvanizing)	
(e) Application of a metallic coating by chemical methods (dipping) or electrochemical methods (electrogalvanizing)	
5. By chemical or electrochemical reaction without diffusion	Subcommittee V on Chemical Treatments
(a) With formation of a chemical compound (oxidation, phosphate treatment)	
(b) Without chemical deposit (pickling and similar operations)	
C—Chemical properties and tests; corrosion tests and corrosion resistant alloys	Subcommittee VI on Tests and Corrosion Studies

oxidation of aluminum alloys — their classification, origin, remedies.

7. Various corrosion problems.

In spite of the relative youth of the committee and the present material difficulties in carrying on this type of experimentation, such studies are underway and some of them have progressed to the point of having publishable results. This is particularly true in the field of defects revealed by anodic oxidation, a matter which will form the subject of a future letter.

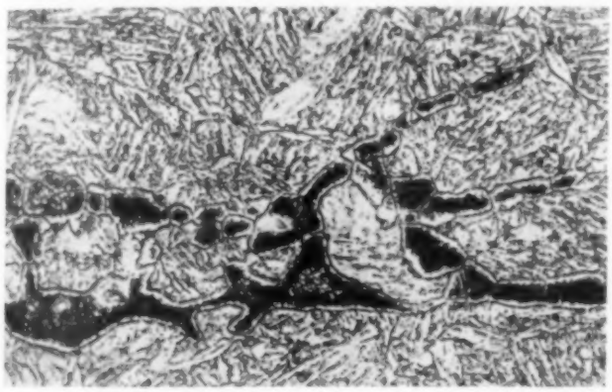
ALBERT M. PORTEVIN
Bessemer Medalist; Consulting Engineer

Fossil Tracks

CANTON, OHIO

To the Readers of METAL PROGRESS:

As an addition to your collection of ghostly presences, materialized under the microscope's lens and photographed thereby, I submit a struc-



ture — possibly the footprint or even the intact fossil skeleton of an extinct three-toed sloth — found in a low carbon, 13% chromium steel bar. Pronounced segregation is revealed at 500× after chromic acid electrolytic etch.

ROBERT J. JOHNSON
Research Metallurgist, Republic Steel Corp.

Alloy Steel or Alloy-Treated Steel?

DAYTON, OHIO

To the Readers of METAL PROGRESS:

The article by Henry T. Chandler on "Alloy Steel or Alloy-Treated Steel?" in the November 1945 issue of *Metal Progress* is of utmost importance at this time due to the release of many different steels upon the market, and therefore warrants attention and discussion.

It appears to me, instead of reverting to old steel definitions of 1915, as proposed by Mr. Chandler, that steels to which one or more reagents or intensifiers have been added could simply be called an "intensified" or "needled" steel. The old accepted numerical designations for steels might be used with the addition of an "I" for intensified — for example, SAE1035-I, NE9440-I, and so on.

Unfortunately some of the intensified steels are not invaluable, as might be supposed from an uncritical reading of Mr. Chandler's article. A few limitations of steels to which intensifiers have been added, with which I am acquainted, are:

1. To obtain maximum effect (hardenability), the austenitizing temperature range must be closely controlled.

2. The temperature at which austenitic grains coarsen is generally lowered.

3. The intensifying agent is rendered ineffective when the steel is held at a high temperature, as required in forging operations.

HOWARD F. BARTELL
Materials Laboratory, Wright Field

Mr. Chandler's Reply

We believe that Mr. Bartell's statement in his last paragraph — "The intensifying agent is rendered ineffective when the steel is held at a high temperature, as required in forging operations" — does require some comment. We have laboratory work now underway on this important point, and the results of this work should form the basis of our reply.

Meanwhile, we may refer interested readers to the paper by R. A. Grange and T. M. Garvey, entitled "Factors Affecting the Hardenability of Boron-Treated Steels", presented before the recent Cleveland Convention.

EDITOR'S EXCERPTS: "Hardenability of the boron-treated steel was decidedly greater than that of the boron-free steel in the vicinity of 1550° F. [C-39 vs. C-31], no better at about 1800° F. [C-32], and appreciably less at 2000° F. [C-30 vs. C-32.5]. [In these experiments small samples were held 15 min. at temperature and air cooled.] This observation indicates that the boron-treated steel would have no greater tendency to air harden than the steel without boron if cooled from ordinary forging or rolling temperatures.

"A boron-treated ingot generally has a lower coarsening temperature than an untreated ingot. All other things being equal, a boron-treated steel has larger austenite grains. The difference was never great enough, at the austenitizing temperature that would ordinarily be used for hardening, to be of any great practical significance. . . . . The grain coarsening effect of boron can be sufficiently overcome by deoxidation with the proper amount of aluminum, which must be added in any event.

"Boron-treated steels, at least when boron is added as ferroboron, may suffer a permanent loss in hardenability if heated for a long period at high temperature. Heating 24 hr. at 2350° F. completely eliminated any increased hardenability due to boron. If boron-treated steels are 'homogenized' — heated well above 2000° F. for many hours or days — the hardenability effect of boron may be completely eliminated."

Russia Plans for the Future—

Excerpts from Premier Stalin's talk as recorded by the Soviet monitor in London from a Moscow radio broadcast, and printed as an Associated Press dispatch in The New York Times *for February 10.*

IT WOULD BE incorrect to think that the war arose accidentally or as the result of the fault of some of the statesmen. Although these faults did exist, the war arose in reality as the inevitable result of the development of the world economic and political forces on the basis of monopolistic capitalism.

Our Marxists declare that the capitalistic system of world economy conceals elements of crises and war, that the development of world capitalism does not follow a steady and even course forward, but proceeds through crises and catastrophes. The uneven development of the capitalist countries leads in time to sharp disturbances in their relations, and the group of countries which consider themselves inadequately provided with raw materials and export markets try usually to change this situation in their favor by means of armed force.

As a result of these factors the capitalist world is sent into two hostile camps and war follows.

Perhaps the catastrophe of war could have been avoided if the raw materials and markets were periodically redistributed between the countries, in accordance with their economic needs, by coordinated and peaceful decisions. But this is impossible under the present capitalist world economy.

Thus, as the result of the first crisis in the development of the capitalist world economy arose the first world war. The second world war arose as a result of the second such crisis.

This does not mean, of course, that the second world war was a copy of the first. On the contrary, it must be kept in mind that the Fascist States, before attacking the Allied countries, had abolished at home the last remnants of the bourgeois democratic liberties, had established a cruel terrorist regime, and had declared for the world to hear that they strove for world domination and spread of the Fascist regime throughout the world.

The entry of the Soviet Union into the war against the Axis powers could only strengthen and did strengthen the anti-Fascist and liberating character of the second world war.

As far as our country is concerned, this was the most cruel and hard of all wars. But the war has not only been a curse; it was at the same time a hard school of trial and a testing of all the peoples' forces.

Eventual victory means, first of all, that our Soviet social system has won [stability], that it has successfully stood the test in the fire of war and has proved its complete vitality. The war has shown that the Soviet social system is a truly popular system, issued from the depths of the people and enjoying its mighty support, fully capable of life and stable. The Soviet social system has proved to be more capable of life and more stable than a non-Soviet social system; it is a better form of organization of society.

Next, our victory implies that it was the Soviet armed forces that won. Our Red Army has won, routed completely the armies of our enemies. This is recognized by everybody — friend and foe. The war has shown that the Red Army was not a colossus with feet of clay but a first-class modern army with completely up-to-date armament, most experienced commanders and high morale and combat qualities; one which could teach others quite a lot.

It would be a mistake to think that one could win such a victory without preparing the whole country beforehand for active defense. It was necessary to have, in addition to unprecedented bravery of our troops, completely modern armament in sufficient quantities.

Can it be said that, before its entry into the second world war, our country already possessed the minimum necessary supplies? I think we can give an affirmative answer. It was the previous three five-year plans that helped to create these favorable material positions. The Communist party knew that war was approaching, that it was impossible to defend the country without heavy industry. [In the previous five-year plans] heavy industry was so developed with the aid of the nationalization of industry and banking. Thereby (and by the collectivization of the rural economy to give the country more bread, more cotton) the Communist party was able to increase war production and to supply the Red Army with the necessary equipment. In the three main years of the war, the party was able to supply the front with sufficient quantities of matériel, our equipment on the whole being superior to the German.

Now a few words on the plans for the work of the Communist party in the near future: The fundamental task of the new five-year plan consists in restoring the areas of the country which have suffered, restoring the prewar level in industry and agriculture, and then exceeding this level by more-or-less considerable amounts.

Special attention will be focused on expanding the production of goods for mass consumption and on wide scale construction of all kinds of scientific research institutes to enable science to develop its forces. I have no doubt that if we render the necessary assistance to our scientists they will be able not only to overtake but also in the very near future to surpass the achievements of scientists outside the boundaries of our country.

Plans for a longer period will enable us to increase the level of our production three-fold as compared with the prewar level. We must see to it that our industry produces 50,000,000 tons of pig iron per year, 60,000,000 tons of steel, 500,000,000 tons of coal, and 60,000,000 tons of oil. Only under such conditions will our country be insured against any eventuality. Perhaps three new five-year plans will be required to achieve this, if not more. But it can be done and we must do it.

Such is my brief account of the work of the Communist party in the recent past and its plan of work for the future.

—and Acquires Some Information on Nucleonics

Russian governmental statement, broadcast from Moscow, as reported by Reuters and printed in the Cleveland Plain Dealer *for February 21:*

THE SOVIET government became aware of the fact that during the latter part of the war individual collaborators of the Soviet military attache in Canada obtained from Canadian citizens of their acquaintance some information of a confidential character which presented no interest to the Soviet organs.

As has been ascertained, this information concerned certain technical data not required by the Soviet government in view of the higher technical achievements in the U.S.S.R., and which could be found in the published works concerning radio location, etc., and also in the well-known American pamphlet "Atomic Energy".

In view of the foregoing, it would be ridiculous to assert that the imparting of such unimportant secret data could create any threat to the security of Canada. Nevertheless, as soon as the Soviet government learned of the above-mentioned activity of some of the collaborators of the military attache in Canada, the Soviet military attache was recalled from Canada in view of the inadmissibility of the activities of these collaborators.

On the other hand the fact must be borne in mind that the Soviet ambassador and other collaborators of the Soviet embassy in Canada were in no way concerned with this affair.

At the same time the Soviet government deems it necessary to call attention to the unbridled campaign, hostile to the Soviet Union, which was opened in the Canadian press and on the Canadian radio simultaneously with the publication of the statement by the Canadian government [about this leak of information].

Interview reported by Associated Press with Joseph E. Davies, former U. S. Ambassador to Russia, printed in The New York Times *for February 19. Commenting on arrests of Canadians for releasing confidential information about atomic energy to foreign agents, he said:*

RUSSIA in self-defense has every moral right to seek atomic bomb secrets through military espionage if excluded from such information by her former fighting allies. Such exclusion is by inference hostile. For years all major powers have maintained intelligence services whose function is to acquire military information available in other nations. If Russia had developed the atomic bomb and the United States were in her shoes, we certainly would try to obtain such information—especially if we faced a potentially hostile world.

The United States and Great Britain are treating the Russians as infants in trying to keep atomic "secrets" from them. Highly skilled Russian scientists will acquire means to atomic warfare within two years in their own laboratories.

We can't have it both ways. Either we obtain full confidence and cooperation among the large nations or we shall find ourselves playing the old game of power politics.

The Russians need peace and their philosophy also requires it. I vigorously oppose the formation of a so-called western bloc of nations. If the Russians get the impression the rest of the world is ganging up on them because of political, economic, racial or religious ideologies, they will take necessary measures to defend themselves against the world, just as any other nation would do in a similar situation. However, that is not the road to peace; it is sowing seeds of war.

The present chaotic mistrust among the United States, Great Britain and Russia must end; the alternative is a gigantic race in armament factories and laboratories resulting in totally destructive war. We should not seek to appease Russia nor should Russia seek to appease us. It is a matter of tolerance, patience and wisdom.

If we fail this supreme test, there will be no vestige of freedom or of anything else to pass on to succeeding generations.

Stress-Corrosion Cracking of 18-8

NIAGARA FALLS, N. Y.

To the Readers of METAL PROGRESS:

In the November 1945 issue of *Metal Progress* Mr. Monypenny referred to the stress-corrosion cracking of the 18% chromium, 8% nickel steel, and briefly reviewed some published information on the tendency of metals to fail in this manner. His specific reference to the A.I.M.E.-A.S.T.M. symposium on stress-corrosion, held in November 1944, led to an example of an 18-8 steel hospital bowl, fabricated by deep drawing, which failed by stress-corrosion.

His photograph represented a highly stressed article in the deep-drawn state, the residual stresses being of the particularly dangerous bi-axial type. The general shape of the bowl was such that unless it were annealed after forming the metal would be left in this condition. It is agreed with Mr. Monypenny that in such condition the bowl would be subject to stress-corrosion cracking, especially in view of the fact that, like all other metals, 18-8 steel can be made to crack if the degree of corrosion and the magnitude of stresses are of a critical order. However, the quoted fact that a number of the bowls cracked before they were placed in service indicates that corrosion was not a primary factor in this instance.

That the austenitic chromium-nickel steels

can be made to crack by stress-corrosion was demonstrated by at least two of the papers given at the 1944 A.I.M.E.-A.S.T.M. symposium, but the data contained in these papers and of any other paper with which I am familiar do not support Mr. Monypenny's strong inference that cold rolling the austenitic stainless steels makes them more subject to stress-corrosion cracking. The data, quite to the contrary, show the reverse to be true — that under the simultaneous influence of stress and corrosion, the cold rolled steels will withstand higher stress than the annealed steels. The influence of stress under given corrosion conditions is shown in the table below, which is a copy of Table VI in the paper entitled "The Susceptibility of Austenitic Stainless Steels to Stress-Corrosion Cracking" presented at the symposium mentioned.

Stress-Corrosion Tests on Uniformly Stressed Cantilever Samples of 17-7 and 18-8 Steels in 42% Boiling Magnesium Chloride Solution

Condition of Metal*	Yield at 0.2% Offset	Tensile Strength	Elongation in 2 In.	Stress on Cantilever Sample	Results
Steel No. 10; 18.54% Cr, 9.01% Ni, 0.07% C					
A.	36,000 psi.	96,900 psi.	55.5	38,000 psi.	No cracking in 170 hr.
				38,500	Cracked in 2 hr.
C.R.	125,000	146,600	18.0	50,000	No cracking in 170 hr.
				59,000	Cracked in 5¾ hr.
				85,000	Cracked in 1⅔ hr.
Steel No. 205; 17.44% Cr, 7.18% Ni, 0.12% C					
A.	38,000	127,700	87.0	37,500	No cracking in 120 hr.
				38,000	No cracking in 125 hr.
				38,300	Cracked in 19¼ hr.
C.R.	157,000	191,400	32.0	30,000	No cracking in 350 hr.
				40,000	No cracking in 55 hr.
				49,500	No cracking in 55 hr.
				58,000	Cracked in 3 hr.
				84,000	Cracked in 1 hr.
				114,000	Cracked in 1 hr.

*A. = Annealed strip 0.035-in. thick.
C.R. = Cold rolled strip 0.035-in. thick.

This table shows that an applied stress of only 38,500 psi. was required to crack a fully annealed 18-8 steel, whereas 18-8 steels cold worked to attain tensile strengths of 146,000 and 190,000 psi. withstood a stress of approximately 50,000 psi. without failure. In Table VII of the same paper data are given for an austenitic chromium-nickel steel, cold rolled to a tensile strength of 194,000 psi. and exposed to the sea-coast atmosphere at Amagansett, Long Island. This steel has been under a stress of 104,000 psi. for 17,000 hr. and no sign of failure has been detected.

These few examples are not submitted to question Mr. Monypenny's observation on the 18-8 steel hospital bowl, but to point out that — although there is a difference in the effect of cold work as applied by deep drawing or by cold rolling — neither type of cold work will cause failure without corrosion effects and the simultaneous existence of critical stress. The same situation applies to annealed 18-8 steels. High internal stresses will result if the 18-8 steel article is drawn too far without annealing, and these stresses will cause failure — as in the case of the bowl. If the deep drawing is controlled and annealing employed in proper sequence, the residual stress will be low and the article will not fail because of stress-corrosion. Incidentally, optimum deep drawing results are obtained with a highly stable, low carbon austenitic steel which work hardens at a slow rate and which contains about 18% chromium and 10 to 12% nickel.

The stresses resulting from simple cold rolling do not exert the same influence, as proven by test and by actual service, because it is then necessary to apply additional high external stress to bring about failure even under drastic corrosion conditions. The only limitation that should be put upon cold rolled 18-8 type of steel concerns ductility. The steel should not be cold rolled to gain excessively high tensile strength beyond a point at which it has so little ductility it cannot be fabricated into the required article.

Reference is again made to the above table. The 17-7 steel was cold rolled to a tensile strength of about 190,000 psi., and had an elongation of 32% in 2 in. This steel has fast work hardening characteristics; its strength increases rapidly on application of cold work by rolling without serious loss of ductility.

Steels of this type, having tensile strengths up to 200,000 psi., have been extensively used for light-weight structures, and failure under atmospheric conditions has not occurred even though the structures have been highly stressed. As pointed out earlier, samples exposed to atmospheric conditions have been stressed to 104,000 psi. without sign of failure. The samples stressed to this extent have been deformed far more than

could be tolerated in a structure, showing that under atmospheric conditions the cold rolled austenitic stainless steels are free of failure by stress-corrosion. This, therefore, represents the wide experience gained through the successful use of these cold rolled steels in this country.

RUSSELL FRANKS
Chief Metallurgist
Union Carbide & Carbon Research Laboratories

Safe Packing and Shipment of Ordnance Parts

MADISON, WIS.

To the Readers of METAL PROGRESS:

The editor's list of suggestions sent to ⊜ members cooperating in the scheme of sending food packages to French metallurgists warrants some comments on the wartime job of delivering matériel to the front in such shape it could be used after getting there.

We have seen so much in the press of the development of spectacular weapons like nuclear fission, the proximity fuse and radar that we are inclined to overlook the stupendous packaging job that was done, particularly in deliveries to the Asiatic-Pacific theater. This very fascinating story of the terrific struggle against corrosion, mildew, rot and physical damage still remains publicly untold.

A few articles have appeared in metallurgical and other publications, but they have dealt chiefly with the most widely known corrosion protection or packaging methods, and not at all with the appalling losses of matériel due to carelessness, ignorance and just plain lack of information — and the almost unbelievable efforts made to correct the situation. Someone should tell the story about the fire-control instruments shipped to North Africa and how, in the first models, some of the instrument components broke loose in the cases and rolled around, grinding up the apparatus like a ball in a ball mill, and how subsequent shipments arrived intact even after they were dropped off the back end of a truck, thanks to redesign of the instrument and the pack. Or how, as late as the fall of 1944, 65% of the matériel arriving in Great Britain was unusable, only 15% being reclaimable, the rest merely junk. Or of the seven piles of junk that arrived on Okinawa, having left the States as seven badly needed complex radar antennae. Or of the 34 B-29 gun turrets which were finally reclaimed at a mid-Pacific base out of a shipment of over 600. The list could be extended to a great length.

What I have in mind is that this story needs telling — the discouraging part, as well as an account of the methods used for solving the problems. Such a story could be amply illustrated by official pictures in the Army's archives.

DAVID J. MACK

Inferior Stainless Cutlery

EAST ORANGE, N. J.

To the Readers of METAL PROGRESS:

The war is over, and our household needed some kitchen cutlery, so I went out and bought a real set which would last for a long time. I have a rack to hold them in; it keeps the edges from becoming dulled. I did not want the 10-cent kind of cutlery since it is made of stainless iron rather than steel, and it cannot be stoned; it is hard only by the cold rolling it received at the steel mill.

My set of seven knives cost me $4.95, or an average price of 70¢, which is considerably higher than the 10-cent line. Since it was labeled "Deluxe" I brought it home.

I now discover that the set is the same old 14% chromium stainless iron and will not hold an edge. A disk-type sharpener will do for a few cuts, but it raises a burr.

It seems to me that the makers of stainless steel should have a real interest in this kind of merchandising. The first function of a knife is to cut and to stay sharp; the *first* function is not to be stainless. I have a couple of carving sets made in the late '20's which are of forged stainless, and they *will* hold an edge. There is so little of this good merchandise in the hands of users that there is a widespread opinion that stainless cutlery cannot be made to keep an edge. To me, as a user, it does seem that when the day comes that industry really wants to make a good knife, there will be too much sales resistance for them to sell it.

PHILIP F. ATWOOD

Aluminum Alloy

Brittle Failure of Hogged-Out Fittings From 14 S-T Billets

By Given Brewer and Herman C. Ihsen
Structures Engineer (now Consulting Engineer) and Metallurgist, Consolidated-Vultee Aircraft Corp., Vultee Field, Cal.

NO LESS an expert metallurgist than Harry McQuaid is fond of repeating that nine out of ten of the "metallurgical" troubles he has tackled in his long experience were solved by improvements in the design rather than by changes in the metal. A stress analyst would likely put the same thoughts in other words, namely, that unforeseen and unallowed-for stresses cause most of the failures. It is therefore of more than ordinary interest to record an instance where a desirable alloy *in a certain commercial form* proved unsuitable for a certain use; stress analysis indicated clearly why it was unsuitable, and metallurgical analysis showed how the trouble could be cured.

The difficulty to be described arrived out of the common practice of "hogging" out large fittings for experimental production from heavy billets, using Keller or Cincinnati duplicating machines, with the knowledge that if the experimental design goes into production the fittings will be drop forged. Although it is generally sensed that a hogged-out part does not have the same properties as a forged part, the differences are usually considered to be minor losses in ductility and are ignored. The part we got into trouble with was made of a long 14S-T aluminum alloy billet. Great length precludes the possibility of longitudinal hot work when rolling from the ingot, with the result that the transverse physical properties are virtually the same as cast properties. The low ductility associated with this cast structure *in the transverse direction* results in a decided reduction in strength of hogged-out parts having "stress raisers" such as holes, notches or other discontinuities.

Once these facts were established we have then found it possible to evaluate the notch sensitivity of 14S-T material through the expedient of boring a hole in the flat tensile coupon. Although the standard tensile test does not show a great difference in strength between brittle and ductile material, tensile coupons containing holes reveal a striking difference in strength. Through such testing it has been demonstrated that improved transverse properties may be achieved by hot upsetting the

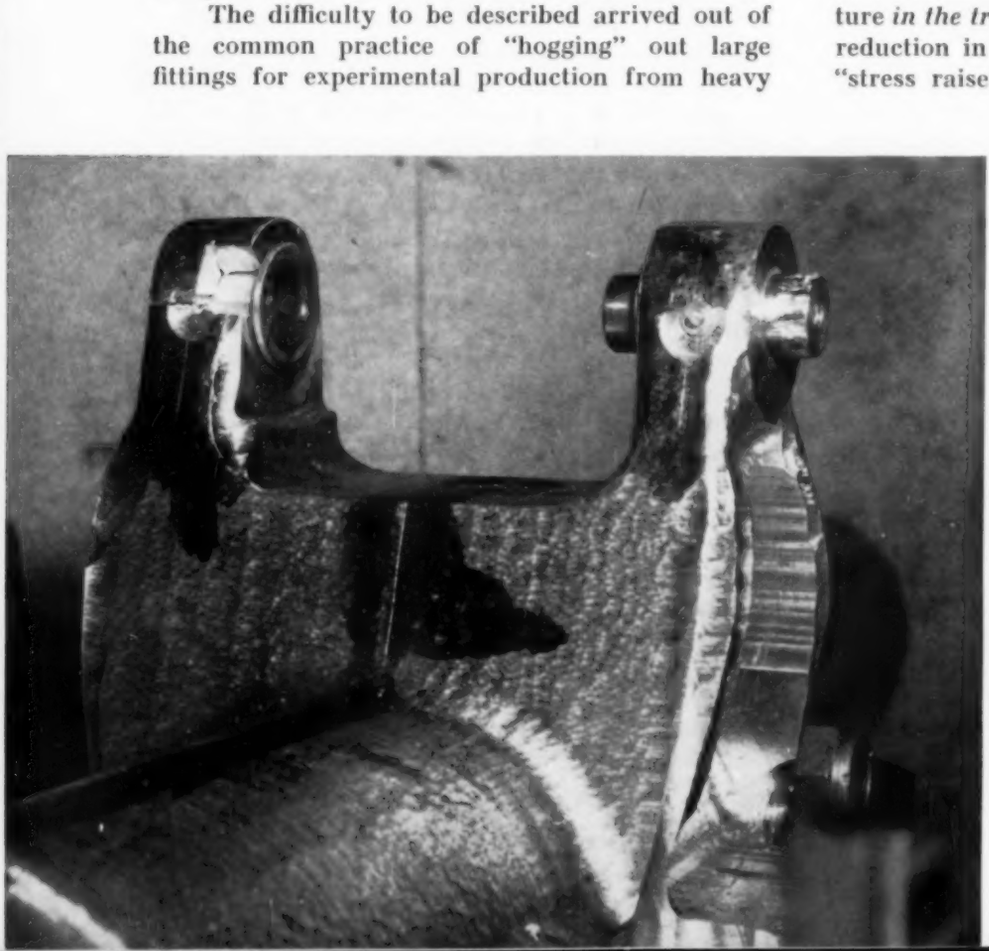


Fig. 1—Photograph of Broken Lug on Fitting Hogged Out of a Large 14 S-T Aluminum Alloy Billet

forged billet before hogging out the experimental fitting. It has also been found expedient to heat treat (water quench) the billet to the 14S-W condition and then do the machining. This alloy possesses much greater ductility in the as-quenched condition and there is less chance of cracking in machining or cutting. The aging to the 14S-T condition is then the final operation, and since it is done at a low temperature (about 340° F.) no difficulty with warpage is encountered.

To be specific: During the static test of a large hogged-out fitting one of the attaching lugs broke out as shown in Fig. 1 at an unexpectedly low load. An investigation utilizing electric strain gages and a photo-elastic model revealed the stress distribution at the zone of fracture to be essentially

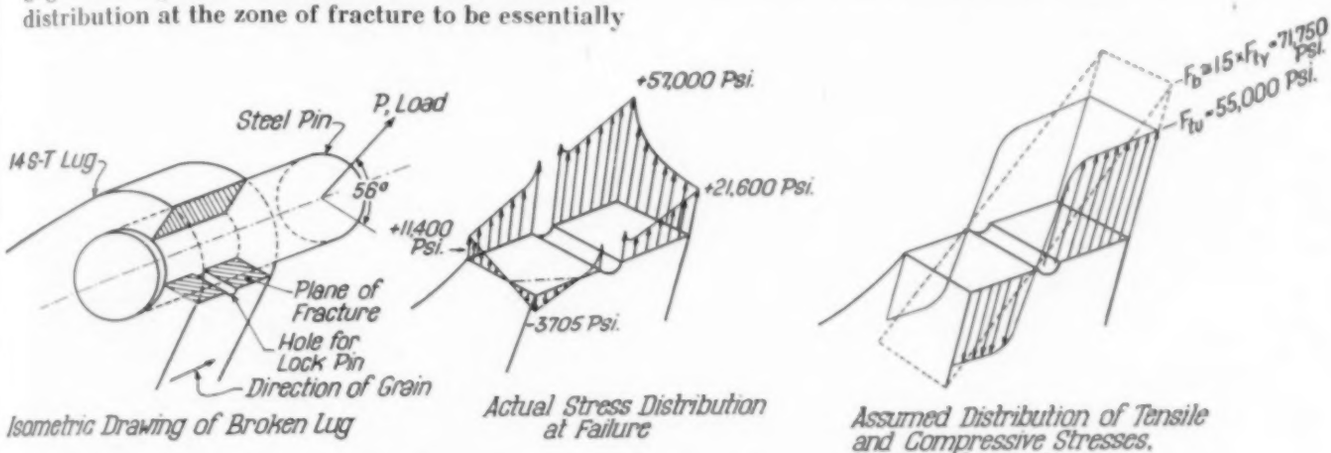


Fig. 2 — Stress Distribution Along Plane Where Tension Failure Occurred, as It Actually Existed in the Lug and as Would Be Assumed to Exist in a Ductile Metal

that shown in Fig. 2. Standard A.S.T.M. round tensile coupons (0.505 in. diameter) were taken from the billet in the longitudinal, transverse and normal (perpendicular) directions, revealing the properties of the billet to be as follows:

	Longitudinal	Transverse	Normal*
Yield strength (0.002 in. per in. set)	—	47,800	45,900
Ultimate strength	63,100	57,800	55,000
Elongation (2 in. gage length)	5%	4%	3%

The actual maximum stress of 57,000 psi. shown in Fig. 2 is about the ultimate strength of the material in the transverse direction. Ordinarily it is assumed that, due to ductility of the metal, yielding will take place and alter the elastic stress distribution illustrated in the central sketch of Fig. 2 to produce a distribution of stress as shown at the right of that same figure. (An extended discussion of the redistribution of stress due to plastic action is given in "Residual Stresses in Wire Loops at Anchorage Shoes or Grommets", an article by Given Brewer in *Metal Progress* for September 1943.)

The stress distribution shown at the right of Fig. 3, as assumed by the stress analyst, is further simplified through the concept of a fictitious stress called the "modulus of rupture" (F_b in usual symbol). F_b is a stress that turns out to be higher than the true ultimate strength of the material in tension, and is computed from the ordinary beam formula relating maximum stress at the extreme fiber with the loads and section shape. This formula is $F_b = \frac{My}{I}$ for rectangular sections, where M is the bending moment, y is the distance from neutral axis to outside fiber, and I is the cross-sectional moment of inertia. The modulus of rupture for this lug was expected to be 71,750 psi., which would have enabled it to carry at least 26% more load than it actually did.

To bring the strength of the lug up to a value sufficient to carry the required load the cross-section could easily have been increased; however, since it was apparent from visual examination and the stress distribution studies that the lug had broken without plastic flow, like a piece of glass at the moment the ultimate stress was reached, it was decided that the problem would not be satisfactorily solved by merely increasing the amount of metal in the lug. A further question left unanswered was the matter of the ductility recorded for round bars, ranging between 3 and 4% even in the transverse directions. This amount of ductility should be sufficient to permit the distribution of stress to approach that shown at the right of Fig. 2, yet apparently little if any yielding took place, the material fracturing while most of the cross-section was still within the elastic range of stress.

To eliminate as many variables as possible a

*"Normal" means perpendicular to the other two directions.

test was devised in which a shape like the unbroken lug was pulled in direct tension; in other words the eccentric load causing bending, as shown in Fig. 2, was removed. The breaking strength of a simple lug in pure tension is readily calculated by the simple formulas

$$P_T = F_{tu} \times A_T$$
$$P_S = F_{su} \times A_S$$

where: P_T = Load causing tension failure of lug
P_S = Load causing shear failure of lug
F_{tu} = Ultimate tensile strength of material, psi.
F_{su} = Ultimate shear strength of material, psi.

For the lug in Fig. 1 and 3:

A_T = 0.714 sq.in. (allowing for lock pin hole and counterbore at spot)
A_S = 1.052 sq.in.

It is assumed in the stress analysis that, at failure, the tensile stress is uniformly distributed over the area A_T and the shear stress is uniformly distributed over the area A_S, as illustrated in Fig. 3. Numerous tests have shown this assumption of uniformly distributed stress to be in reasonable agreement with the experimental evidence for ductile materials.

Utilizing the simple formulas for lug tear-out, the breaking load of the symmetrically loaded lug was calculated using handbook values of allowable stress. The lug was then loaded to destruction in a testing machine, failure occurring in tension. It was predicted that the lug would break under a tensile load of 39,200 lb., the computed breaking load in shear being higher, namely, 42,000 lb. In the actual test, the lug broke in tension but under a low load, namely, 27,800 lb. This load divided by the area (reduced, as noted, by drill hole and spot facing) corresponded to an average tensile stress at failure of 39,000 psi., considerably under the ultimate strength for the same material (55,000 psi.) as determined from the round bar tension test. In the light of this evidence it was quite apparent that the lug material had insufficient ductility to permit sufficient plastic flow to occur and produce the uniformly distributed stress assumed in the calculations.

Flat tensile coupons, 1.50 by 0.24 in. in the reduced section, were made from the 14S-T billet in the transverse direction and from a plate of 24S-T known to have high ductility. A 100-line-per-inch photo-grid was printed on them and the coupons were pulled in tension with these results:

	14S-T	24S-T
F_{tu} (ultimate tensile strength)	53,660	68,800
F_{ty} (yield; 0.002 in. per in. set)	45,300	46,600
Elongation, in 2-in. gage	3.0%	18.5%
Elongation, in 0.01-in. grid	8.0%	35.0%

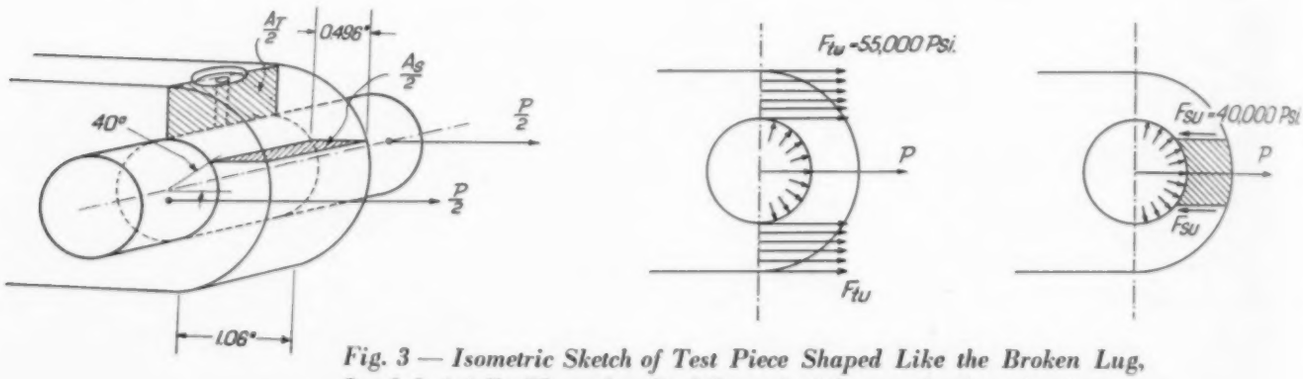


Fig. 3 — Isometric Sketch of Test Piece Shaped Like the Broken Lug, Loaded Axially Through a Steel Pin. At right are sketches showing assumed uniform stress distributions in tension (center) and shear (right)

Test lugs were then made of these same materials, similar in outline to the shape shown in Fig. 2. The radius of the loading pin was $\frac{7}{16}$ in.; the exterior radius of the lug was $\frac{7}{8}$ in. Other important dimensions were

	14S-T	24S-T
Thickness	0.237 in.	0.225 in.
A_T (area in tension)	0.2075 sq.in.	0.197 sq.in.
A_S (area in shear)	0.235 sq.in.	0.223 sq.in.

Results of tension tests to destruction are shown in Table I and give evidence of the fact

Table I — Comparison of Predicted and Measured Breaking Strength of 14S-T and 24S-T Lugs

		Tensile, at Fracture		Shear, at Fracture	
		Load	Stress	Load	Stress
14S-T	Predicted	11,100 lb.	53,600 psi.	9,410 lb.	40,000 psi.*
	Measured	9,200	44,300	9,200	39,200
24S-T	Predicted	13,560	68,800	8,925	40,000*
	Measured	12,350	62,250	>12,350	>55,400

*Values from manufacturers handbook.

that the formula for lug strength in *tension* agrees fairly well with test results for the ductile 24S-T but is optimistic for the brittle 14S-T in the transverse direction. The formula for lug strength in *shear* proves to be unduly conservative as applied to 24S-T and is just about correct for brittle 14S-T. The reasons for the better agreement with theory on the part of the 24S-T, in so far as tension failure is concerned, can be discerned in the distributions of strain and stress at failure as determined from the photo-grid screens on the lugs. See Fig. 4 and 5. It should be noted that the 14S-T lug failed simultaneously in tension and along the shear plane at a load of 9200 lb., whereas the 24S-T lug failed in tension. In the latter, therefore, it is impossible to say more than that the ultimate shear load is higher than the breaking load in tension.

It should also be remarked that, due to tearing and the difficulties in accurately measuring the very small strains on the 0.01-in. grid associated with the 14S-T material, the stress distribution for the 14S-T lug as shown in Fig. 5 (right-hand sketch) is higher than is compatible with the breaking load of the lug. (It figures to be about 9800 lb., whereas Table I shows the lug to have broken at 9200 lb.) On the other hand, the stress distribution shown for 24S-T material, when averaged over the lug cross-section and multiplied by the tension tear-out area, A_t, yields a breaking load of 12,500 lb., which is in good agreement with the actual breaking load of 12,350 lb. Therefore the estimated stress distribution on the 24S-T lug seems to be valid. If the tensile stress distribution across the lug

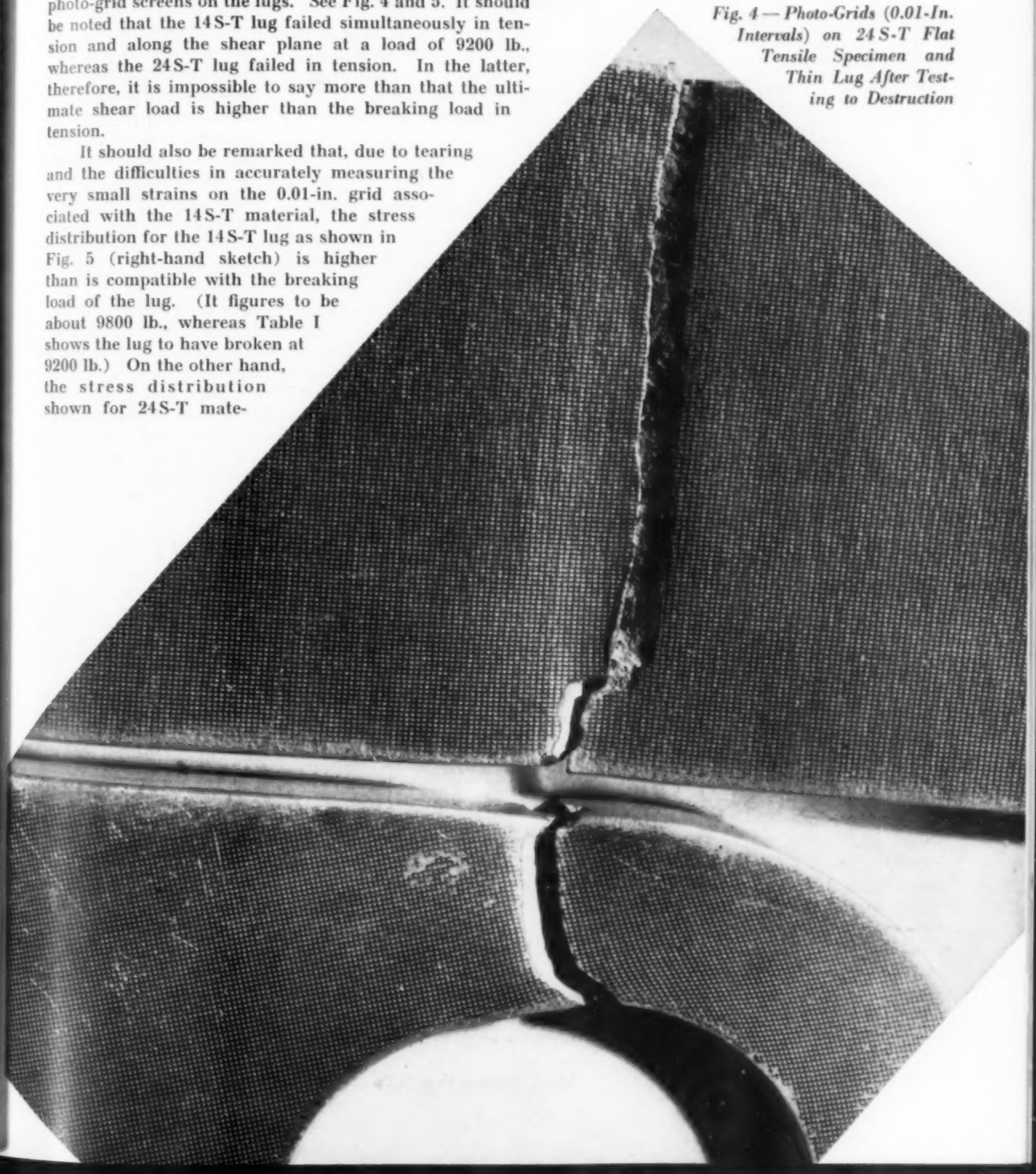
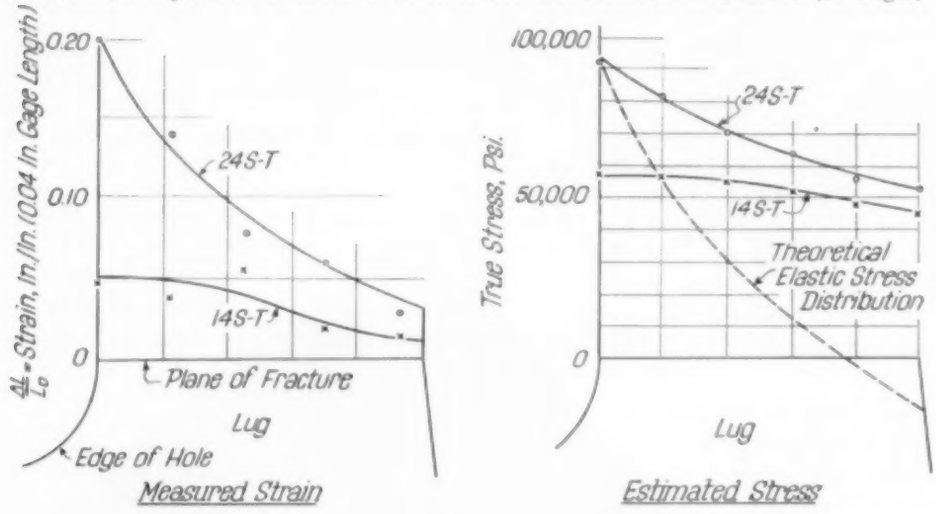


Fig. 4 — Photo-Grids (0.01-In. Intervals) on 24S-T Flat Tensile Specimen and Thin Lug After Testing to Destruction

Fig. 5 — Strain Distribution in Thin Lugs, as Measured From Photo-Grids After Failure (at Left) and Estimated True Stress Distribution at Failure (at Right)



at failure is compared to the elastic distribution (that is, before yielding has taken place) as shown by the dotted line in the right-hand sketch, it seems that the assumption of a uniformly distributed stress incorporated in the formulas for lug strength is fairly well founded in fact, although the ultimate strain distribution after failure shown in the left-hand sketch of Fig. 5 is far from uniformly distributed and resembles the elastic strain (or stress) distribution for the lug.

It was fairly evident, although not conclusively demonstrated, that the 14S-T billet had far less ductility than the 24S-T, and therefore the former was more sensitive to stress raising discontinuities than the latter. It also seemed apparent that the standard round or flat tensile coupon could not sufficiently distinguish between good and bad material. It was therefore suggested that a flat tensile coupon be made standard except that a large drilled and reamed hole be put in the center. See Fig. 6. The presence of the hole does not cause a large stress concentration at its transverse diametral plane; however, such tests made on the "brittle" 14S-T material revealed a good separation between materials in the range of low ductility. This is clearly shown in Table II.

It should be remembered that only the longitudinal properties of large 14S-T billets are guaranteed by the maker to meet the specifications while transverse are not. Furthermore the handbook values for transverse properties do not apply to billets having a length greater than twice their width. Since the 10 x 20 x 72-in. billet shown in the first line of Table II was considerably longer than twice its width, and as its microstructure indicated that the metal had not received any hot work in the longitudinal direction, its transverse properties were understandably poor. The 11 x 16 x 20½-in. billet, as shown in the table, had less sensitivity to the hole test and a little better ductility.

In an effort to improve matters still further it was suggested that if this billet were upset and drawn out in the longitudinal direction the overall properties might be improved. Consequently three such billets were upset into cubes and then drawn out to original dimension, this procedure being repeated three times at forging temperature. Hole tests from these after the hot

(Continued at bottom of page at right)

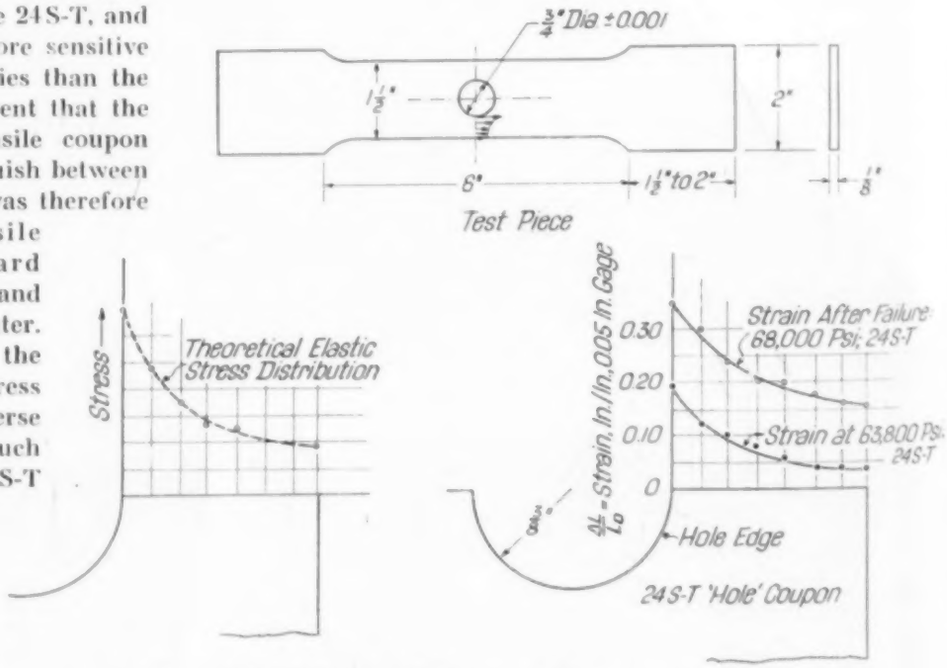


Fig. 6 — "Hole" Coupon, Theoretical Elastic Stress Distribution Across Transverse Section at the Hole, and Measured Strain Distribution on 0.05-In. Grid at 63,800 Psi. and After Failure

Brittle Fittings

work indicate an appreciable improvement in physical properties and less sensitivity to stress raising discontinuities, all as shown in the last line of Table II.

Conclusions — It was concluded on the basis of these studies that the "hole" coupon is a good criterion for detection of notch sensitive properties found in some 14S-T billets, when the coupon is cut transversely and tested in tension in the ordinary way. It was further decided that billets for making large hogged-out fittings should be upset and drawn out at forging temperature before being machined, this procedure apparently yielding a material possessing better ductility and less sensitivity to stress raising discontinuities. It should be pointed out that the difficulties encountered with the 14S-T billets do not extend into the field of 14S-T extruded or plate stock; in such materials it has been shown that 14S-T has *less* sensitivity to round notches than 24S-T.

Table II — Average Tensile Results of Tests on 14S-T Billets; Round and "Hole" Specimens

Size of Billet	Direction of Tests	Standard Round Coupons					Hole (Flat) Coupons		
		Number	Yield	Ultimate	Elongation in 2 In.	Reduction of Area	Number	Ultimate	Gain*
10 x 20 x 72 in.	Transverse	2	46,850	56,400	3.5	—	8	44,030	—
11 x 16 x 20½ in.	Transverse	6	50,700	61,900	5.1	6.6	6	52,400	19%
Same after hot working	Random	5	61,400	68,500	6.0	8.0	9	58,300	32%

*Gain over 44,030 psi., ultimate strength of the 10 x 20 x 72-in. billet, whose dimensions and macrostructure indicated it received comparatively little hot work in the transverse direction.

Specifications, New Style

The Heckled Band

By D. Carb
Pittsburgh, Pa.

I HAVE LESS HOPE of remembering the different types of alloy steels than I have of hitting the Daily Double which is remote indeed and in my time I collect many unnegotiable coupons to whit. In the course of a day I encounter an assorted number of NEs, SAEs, AISIs and an occasional WD which sometimes causes me to talk to myself concerning letters in general. They never seem to be able to make up their minds on the exact Chemistry even in one grade so that aside from the prefix I have to add a date on the back side.

I flounder along making the best of things marking down the proper letters before and the proper numbers behind also whether its EF or OH when one day I find a specification from our nastiest customer in which immediately behind the grade there is a capitol H. I comply reverently with the suggestion but in looking through a couple of Bibles I can't decipher the H and start to think maybe it's a typographical.

We check all our paper work and find they very plainly want the steel H. I turn it over to Sales as my best guess is that they want it in a hurry and as delivery and promises are none of mine I feel justified. The next day Sales gets me in a three-way and the Fellow I can hardly hear makes remarks disparaging. I am left with the impression that the H is of considerable metal-

lurgical significance and what's more it's a standard recognized specification.

In desperation I finally ask the Chief who is always in the groove on such things. He nods yes and tosses me a gray folder marked Manual 11. I immediately suspect collusion as I notice the AISIs and the SAEs publish this gazette jointly. I scan the book and find sure enough that someone wasn't satisfied with the old jumble so they add the H behind some old grades to ensure chaos.

On further study though I see the chemistries aren't like the old Steels. When you H the grade the chemistry ranges seem to widen out automatically which is certainly a novel way to get rid of the heats the AISIs make on Pay Day. Of course I know from experience that the SAEs get paid too and these coincidences cause us much discomfort. One outfit must get paid every week as they are much too often lifting the forgings we send them out of their quench tank in more than one piece which causes them to yell into the pipe what comes out at our end "Stinker" or .....* These matters are always handled promptly by the companys' respective smoothy's and its usually a toss up who loses face. Such encounters between the AISIs and the SAEs and us Forgers have always been most exciting so that I am now very disappointed to find they merge like the new gazette would indicate, as I love a good contest. I often root for either side depending on my instructions from the chief who always has the thing handicapped so that we at least Place.

I start to wonder who the AISIs and SAEs join up against and the thought that it might be us poor forgers is so foreboding that I read the new rules backwards and forward for two consecutive nights much to the disgust of my Cupcake who is more frivolously inclined.

The game as they now outline it in Manual 11 looks like we are going to play for hardenability chiefly which of course makes Sense. However their end quench jominy Curves are in the form of bands rather than single lines like I get when I run the test. I begin to suspect that maybe the Little Steel Formula carries a clause about paying people by the day so that out of necessity the AISIs have to be allowed more tolerance or enlist the help of the WCTU.

About two days after these developments I happen to meet one of our traveling Friends who represents one of the AISIs at the local Gin-Mill. We work over a few suds at his expense and I casually remark that we appreciate steel making is a science not an art but how come they suddenly get so artless as the H book plainly discloses.

To this remark he takes personal affront and starts drawing curves all over the table cloth simultaneously making with metallurgical harangue faster than I am eating the pretzels which Rudy always has handy for his paying customers. My friend says that if everybody changed over to H steels he would not come and see us half so often. I answer that I dont blame him for not showing his face as I too would be ashamed to admit I belong to the mob who originates such a scheme.

I am trying to catch Rudy's eye to indicate refills when my acquaintance calls my attention to what he has been drawing on the white cloth. He says here are the limits of hardenability we get under the old system and there is what we will get under the new. The new band is but the middle third of the old and he asks do I see the light. Before I can nod he recalls a few Heats they ship us sometime back which passed the old chemistry but which we couldn't get hard enough no how. He points out that with H steels this can't happen as they guarantee hardenability and won't ship anything that doesn't meet the band and all we have to do is order the proper grade and everybody's blood pressure will return to normal in no time.

I ask how are they so certain about all this and take another of the Visitor's cigarettes. He informs me that everybody for years has been squawking that the hardenability they get in any grade shows too much difference from heat to heat or from mill to Mill. The AISIs and the SAEs decide to take them at their word and narrow the hardenability range. This they do by taking the limits of the old steels and knocking off the top and bottom portions so that they end up with the middle third of the old band. This agreement I am told took place only after much study, loud talk and bending of the right elbow but finally they all agree and there it is. I slough off the last in the glass and try to change the subject as I am now very sorry I get my friend started but he's hotter than the back end of a buzz bomb. I loosen my tie and wonder if what Rudy has been tapping from the center spigot is extracted from pitch blende.

My pal brushes aside my observation of the lonesome looking Cheesecake at the next table and says the only reason they widen the Chemistry ranges of the H steels is so they can have room to make small adjustments — "adjustments", that's what he says — of the different elements while melting in order to hit the hardenability Band. I have reached the point where for some reason I am enthusiastic about all things so I say maybe when we buy H steels we will receive fewer wires

*Censored by Editor.

about - - - - - off heats. My buddy slaps my shoulder and tells me I'm now on the Beam as that is exactly so. Further he continues we will get steel of much more consistent hardenability and I won't have to be forever changing the draw temperatures and fooling with trial pieces in our own heat treat.

This appeals to me so I start to fold up the table cloth and stuff it in my pocket as a future reference in the shop. Rudy very promptly comes from behind the counter and says he observes my actions which he terms highly unethical, particularly to a man of my position. I censor Rudy for getting his nose out of joint over trivialities and patiently explain that inscribed on the cloth is data of considerable importance to the welfare of Mankind and as such is to be Preserved and Treasured and from now on the cloth is not for washing and pressing and soaking up the dew which the assorted rumpots of the place splash about. Rudy wants to take it up with the OPA or someone. I stand on my rights and recite the four freedoms* at the top of my voice. Rudy is starting to roll up one sleeve when my friend sticks enough lettuce into his fist to buy a dozen cloths.

We get to the door in a hurry as it appears we have unintentionally incited riot. Due to the turn of events I suggest to my Pal that possibly we had better confirm our discussion by daylight. He promptly swears on a stack of beer cases that everything has been the whole truth but I'm still somewhat dubious as in stepping out the door he loses his footing to such an extent that I seriously question the propaganda I read in the monthly blats about nothing rolls like a Ball.

The next morning I bang the time clock in a photo-finish and am at my desk rifling the middle drawer for the bottle of white tablets when the phone rings. The Chief shouts come in in a tone he reserves for special occasions like the time I put four thermo-couples into the lead pot without first inserting them in the long hollow tubes. I swallow two pills on the way to his Office and ease into a chair hoping he won't look up for a couple of hours. But he promptly tosses me a batch of requisitions and asks did I specify the steel grades. I answer in the affirmative and he accuses me of not filling in the blank on specified hardenability. I counter that this feature is no longer necessary as the hardenability on H steels is guaranteed.

The Chief says I should read the book. I state I read it both ways including upside down and further that just last night I take a post-graduate course at Rudy's. He bellows he's not talking about the Racing Form. As we are obviously at

Rudy Very Promptly Comes From Behind the Counter

*Verbatim ac literatim, pace Indonesian.

an impass I indicate I would appreciate his coming to the point as I have lost the thread of Thought. He intimates I am very likely to lose something else and that if I will kindly study the aforementioned document I will find out what the score is. At this precise moment my companion of the previous night makes his appearance in such a cloud of cordial greetings and smiles and pumping of the right arm that I am extremely envious of his Constitution.

It develops that the affable one has called to clarify the matter of our specifying H steels without saying anything about minimums or maximums or distances. I accuse him of welshing on what the AISIs and SAEs print very legibly in band form in their recent publication Manual 11. The visitor says I didn't read closely — which is where I came in (see above). The Boss who seems to be enjoying our discourse motions for the Smooth One to proceed.

I find that although they publish hardenability bands it's just a come-on because when you order H steel you're hog-tied to two minimum or two maximum Rockwells or one of each at a certain distance but not both and so on. I'm about to shout "We Wuz Robbed" but I notice the chief so far seems to be in agreement with the one on horseback. The boss and the scoundrel then decide what Jominy distances are the ones that really mean something in the parts in question. I am not enjoying this situation and fervently wish the Boys out in the lab would stop pulling tensiles for awhile as my head has developed one long reverberating echo from each Bang. From the furious pace they are setting in pulling the tests I wonder if they have not recently been put on an incentive plan.

The two schemers finally come to agreement on the right end quench distance but when my erstwhile traveling AISI Friend looks at the minimum Rockwell the Boss writes he gets exorcised and starts thumbing the pages of the gray covered gazette. My interest quickens as the visitor points out that what the Chief wants is 3 Rockwells above the minimum shown on the band at that distance and the Boss says so what? The other one who is fast getting in a lather says what we are trying to do is not cricket and I remind him it is as Hoyle as what he tells me a minute before about the bands not applying to the whole band but only to a point here and there. My AISI Friend insists that this method is the best his outfit or anyone else can do and plays on our Sympathies by recalling the band steels are a great improvement over what we used to get and what's more They charge no more for H steels than the old kind so why are We trying to hunch on a good thing.

The Super now chips in and says he hears it is possible to get restricted bands in H steels from the AISIs and that's what he wants and will get come everything. Now the AISIs and SAEs are formidable people in our Business and although I admire the Chief's duodenal audacity I doubt the wisdom of such a stand. So when the visitor acknowledges to the Chief that we can get restricted Rockwell limits if we want them I want to snake dance around the specimen cases but don't when he renigs by saying *only* on special steels like aircraft quality. The Super demands isn't it true that the same melters and furnaces make regular Electric furnace steel as make special Quality? The outsider says Yes but they have to guarantee so many things including the disposition of the Girls on the magnaflux machines that the steel has to be near perfect and although they might lose their shirts they are willing to try to work to restricted bands on such orders. The Boss remarks that at thirty bucks a ton they can afford to lose plenty of shirts plus a pair of Pants now and then but the good looking one denies all this.

We get back to the issue by insisting that the minimum Rockwell we want at the critical distance must be higher than what the book shows and imply the AISIs and SAEs should revise the Gazette accordingly. The masked marvel says phooey to us and that if we need more hardenability we had better overhaul our quench tank. The Boss is in violent disagreement and recalls that the H bands were figured on heats made to the old chemistry and will gamble that the AISIs and SAEs don't have enough dope to be so sure they are absolutely correct with heats made to the new analysis. In fact he goes on to demonstrate that they themselves admit this by calling Manual 11 tentative. The one who could sell square-wheeled bicycles to the cliff dwellers defines tentative as the Law until proved otherwise and cautions us to stay in line lest when the bands are revised as they someday will be it might be found necessary to widen instead of squeeze them.

We break up rather abruptly when the Chief very quietly and very slowly says OK he'll stick to the band on this steel order but that the Parts had better come out of the heat treat at the right hardness or else. The AISI pats my shoulder and says as how I'm such a good stick with the furnaces and tanks and all that nobody has anything to worry about.

As I walk over to see if I can somehow muffle the loud explosions coming from the tensile machine I can't help thinking that while we might have a new set of rules on alloy it's still the same old game.

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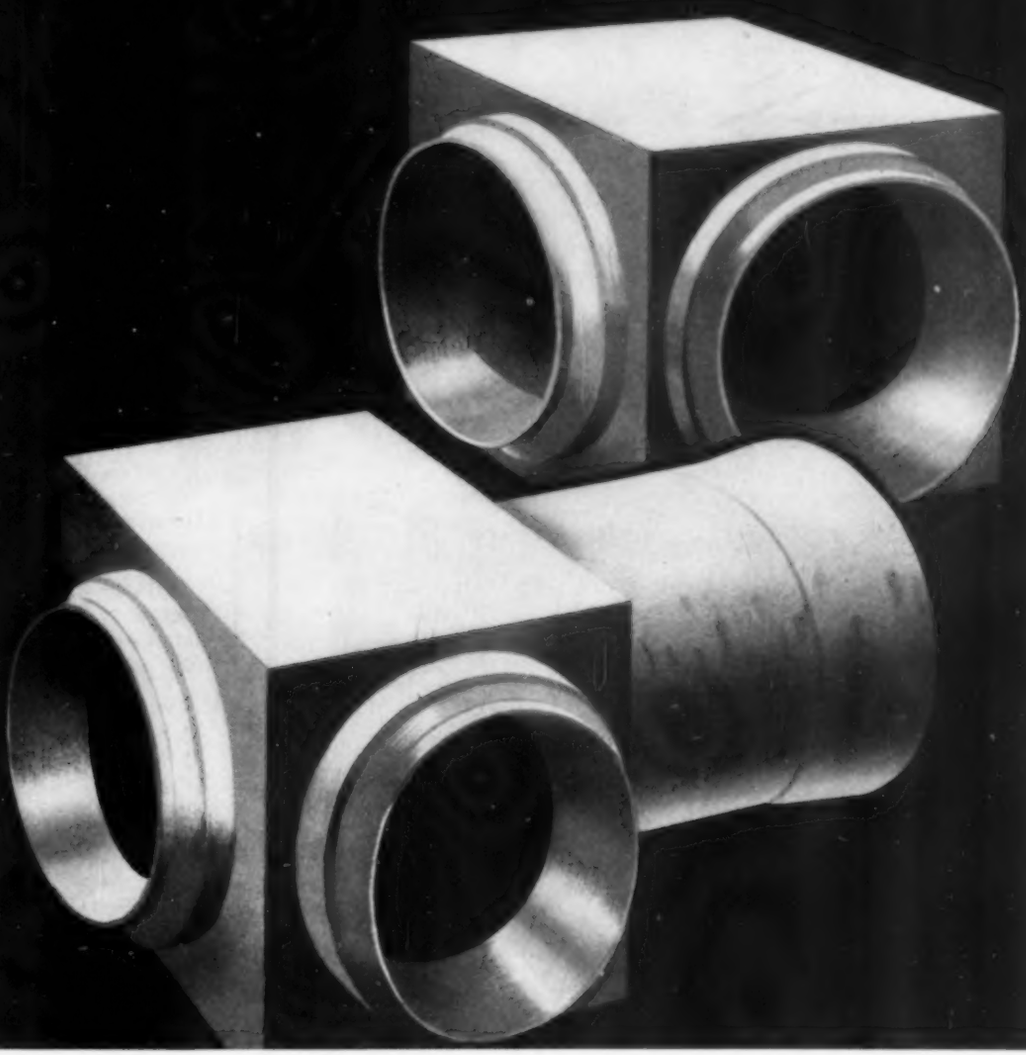

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Personals

ERNEST O. KIRKENDALL, formerly assistant professor at Wayne University in Detroit, is now secretary of the Metals Divisions of the American Institute of Mining and Metallurgical Engineers, New York.

D. F. MURPHY has been appointed chief metallurgical engineer of the Besser Mfg. Co., Alpena, Mich. He formerly held the same position with the Struthers Wells Corp.

Having been released from active duty with the Navy Bureau of Ordnance, ARDEN L. KNIGHT has taken the position of eastern New England sales manager for Braeburn Alloy Steel Co. with offices in Boston.

WILLIAM R. KUCHS has been transferred from engineering research laboratory at North American Aviation, Kansas City, Kansas, to materials and process engineering department at North American Aviation, Inglewood, Calif.

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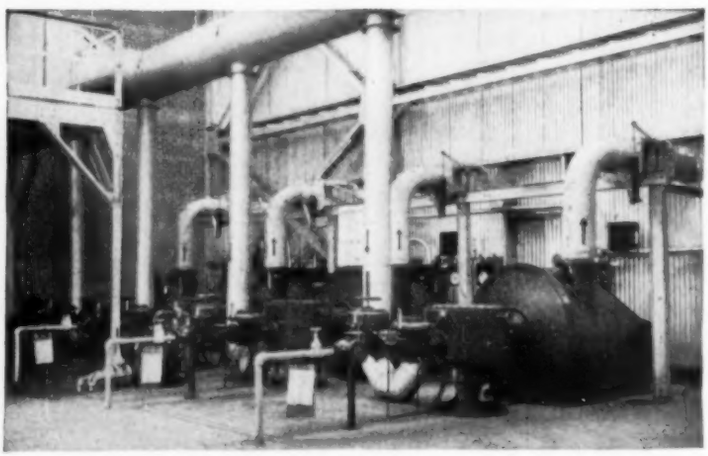

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THOMAS C. FORD has been appointed district manager of the Pittsburgh office of Electro Metallurgical Sales Corp.

EUGENE G. GRACE, formerly president of the Bethlehem Steel Co., has been elected chairman of the board.

HENRY H. SCOTLAND is setting up a consulting practice in metallurgical engineering in Toronto, Canada.

After severing his connection with Victory Aircraft, Ltd., of Malton, Ont., WILLIAM G. CLARIDGE has associated himself with a group of engineers to form the Industrial Liaison Rota, Toronto, Canada, a research and industrial development service.

LEWIS C. CAVALIER, formerly with Pennsylvania State College, has taken up his duties with the Carnegie-Illinois Steel Corp., Pittsburgh, as metallurgist in the quality control division.

After five years as metallurgist with Wright Aeronautical Corp., JAMES G. BIELENBERG has joined the research laboratories of the Douglas Aircraft Co. in the same capacity.

DAVID L. NEWHOUSE is now metallurgical engineer at the works laboratory of the General Electric Co. in Schenectady.

After being released from the U. S. Navy, RAYMOND H. W. HEARTEL accepted the position of metallurgical engineer with the Western Electric Co., Kearny, N. J.

DONALD L. CLUPPER, formerly chief chemist of Remington-Rand Propeller Division, is now materials engineer for the pneumatic tool division of Ingersoll-Rand Co. at Athens, Pa.

KURT F. ZIEHM, JR. has been appointed chief metallurgist at Badger Brass & Aluminum Foundry, Milwaukee, Wis.

W. B. F. MCKAY is taking graduate work at the University of Minnesota following his release to the R.C.A.F. reserve.

G. L. KEHL has returned to his position at the Columbia University, School of Mines, after being associated with the Los Alamos project.

EDWIN F. MITCHELL has been appointed manager of alloy castings sales for Continental Foundry & Machine Co., Chicago.

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Personals

LLOYD R. CLOWES, formerly Pittsburgh district manager of Firth-Sterling Steel Co., has recently been appointed assistant general sales manager of that company.

GERRIT DEVRIES, formerly assistant metallurgist at the Bureau of Standards, is now employed at the Naval Proving Ground at Dahlgren, Va., as associate metallurgist.

A. F. TENNEY, heat treating and metallurgical specialist, has been appointed southern Ohio district sales manager of Lithium Co.

Metal Hydrides, Inc. announces the appointment of DANIEL S. EPPELSHEIMER as sales manager and chief physical metallurgist. Dr. Eppelsheimer heretofore served as acting director of the engineering experiment station of the University of New Hampshire.

Eutectic Welding Alloys Co. announces the appointment of ALBERT ZEISEL, formerly midwestern sales manager, as assistant in charge of sales for the entire company.

FREDERICK COOPER, formerly with the Wilson Steel & Tool Co., has been made salesman for the Vanadium-Alloys Steel Co. in the Philadelphia district.

R. A. PETERSON, formerly metallurgical engineer with the Packard Motor Car Co., is now sales engineer for the Bunting Brass & Bronze Co., covering states of Indiana and Kentucky.

JAMES M. LOIACONO has been transferred by the Bendix Aviation Corp. from the Philadelphia division to the Eclipse-Pioneer division, Teterboro, N. J. He is senior metallurgist at the latter place.

ALFRED I. MALLIN, formerly with the Wright Aeronautical Corp., is now doing radiographic work for the Dayton Industrial X-Ray Laboratory and Supply Co., Dayton, Ohio.

CHARLES H. FUCHSMAN is now connected with the research division, International Minerals and Chemical Corp., Carlsbad, N. M., following the termination of his connection with the U. S. Bureau of Mines.

L. C. GORHAM, president, Gorham Tool Co., Detroit, has been elected as a director of the Cutting Tool Manufacturers Association.

ARTHUR D. BEERS, formerly assistant superintendent of the Gary Steel Works central mills, has been promoted to superintendent.

R. S. JANE, formerly director of industrial research department of the Shawinigan Water and Power Co., has been appointed vice-president in charge of research of Shawinigan Chemicals, Ltd.

C. M. CARMICHAEL, manager, stainless steel and alloys division of the Shawinigan Water and Power Co., has been appointed vice-president.

The Aluminum Co. of America has transferred KENNETH B. BLY from the Kansas City foundry to the Cleveland permanent mold foundry where he will be department metallurgist.

THOMAS C. EVANS, formerly with Remington Arms Co., is now metallurgist at the technical section, ammonia dept., E. I. du Pont de Nemours & Co., Belle, W. Va.

MELVILLE F. COOLBAUGH has retired from the presidency of the Colorado School of Mines after 25 years' incumbency. He was a graduate in science of Colorado College and became an international authority on the sources of radium and other radioactive metals. Prior to his presidency he was director of metallurgical research for the Metals Exploration Co.

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Personals

W. E. MAHIN, formerly with Westinghouse Electric Corp., has become chairman of metals and minerals division of the Armour Research Foundation, Chicago.

H. C. AMSTBERG has been appointed manager of metallurgical engineering at the East Pittsburgh works of Westinghouse. He was formerly manager of the metallurgical application section.

The degree of Doctor of Science in metallurgy (*in absentia*) was conferred on O. W. ELLIS, director of Ontario Research Foundation, Toronto, by the University of Birmingham, England, on Dec. 15, 1945.

The International Nickel Co., Inc., has appointed GEORGE A. FISHER, JR. to direct the newly opened St. Louis technical section of its development and research division.

STEPHEN P. GAZOORIAN has joined the staff of Derry Plan, Louisville, Ky.

LT. COL. CHARLES H. GREENALL, now director of research at Frankford Arsenal, will become executive director of the Franklin Institute Laboratories, Philadelphia, on or about April 1, 1946.

The Edgcomb Steel Co. announces the appointment of J. RAYMOND SMITH, formerly assistant to general sales manager of Rustless Iron and Steel Corp., as district manager in Baltimore.

R. DAVID THOMAS, JR., director of research and engineering of Arcos Corp. since 1940, has been elected vice-president of the company.

C. G. CHAMBERS, formerly with the Wayne Division, Bendix Aviation Corp., is now process development engineer with the General Motors Corp., Detroit.

JOHN E. FRIESS is now with the General Electric Co., Schenectady, N. Y., as proposition engineer in the industrial heating division.

SIDNEY SIEGEL was honorably discharged from the U.S.N.R. and has accepted a position as a staff associate on a metallurgical project at Massachusetts Institute of Technology.

JOHN M. MARCHI, formerly with the Trentwood Rolling Mills, is now mill metallurgist at the Aluminum Co. of America's fabricating plant at Alcoa, Tenn.

EMERY B. GEBERT has accepted a position with the Hungerford Research Corp. in Murray Hill, N. J., as chief powder metallurgist.

MORTON GERLA, formerly ordnance engineer with the aviation ordnance design division of the Naval Gun Factory, is now division engineer with the Shirgun Corp. in New York City.

W. J. LAWLER, formerly extrusion metallurgist, New Kensington Works, Aluminum Co. of America, is now sales engineer for magnesium wrought products with the White Metal Rolling and Stamping Corp., Brooklyn, N. Y.

GLENN BRANCH, having terminated his connection with the Gates Rubber Co., has formed a partnership with S. S. Daykin of Daykin Engineering Co., Cleveland, engineers and distributors.

HENRY A. VAN HALA has been transferred to the Cleveland sales office of the Bristol Co. from the Birmingham office.

C. K. LOCKWOOD has been appointed sales manager of the stainless steel and alloys division of the Shawinigan Water and Power Co., Montreal, Canada.

JOSEPH MAZIA, formerly with the ordnance research laboratory, Frankford Arsenal, is now metallurgist in the metal surface treatment division of the American Chemical Paint Co., Ambler, Pa.

BILL CULBERTSON became associate professor of metallurgy at Case School of Applied Science, Cleveland, on March 1. He had been with the Army Ordnance Department for 4½ years.

Alloy Rods Co. announces that GUSTAF A. OSTROM has been appointed chief research engineer. Mr. Ostrom was formerly employed as welding engineer for the Foote Mineral Co.

STERLING T. BOYD has been transferred from chief inspector to plant metallurgist by the Colonial Steel Division of Vanadium-Alloys Steel Co., Monaca, Pa.

C. B. CALLOMON has taken over the Metal Control Laboratories of Los Angeles after severing his connection with the Western Gear Works, Lynwood, Calif.

CLAUS G. GOETZEL, technical director of American Electro Metal Corp., Yonkers, N. Y., has been appointed adjunct professor of chemical engineering by New York University to teach a newly established lecture and laboratory course in powder metallurgy.

CHARLES E. HARVEY has resigned his position as senior chemist, Naval Shipyard, Mare Island, to return to Applied Research Laboratories, Glendale, Calif., where he will take charge of research in methods of spectrographic analysis.

. . . for better machining of tough materials—

• Each machining job is different. ThredKut 99 can be used straight or diluted to fit job requirements. Stuart Oil Engineers, "skilled in the art" can adapt this perfectly balanced heavy duty cutting oil to give the results you are looking for. D. A. Stuart Oil Co., Limited, 2743 So. Troy Street, Chicago 23, Illinois.

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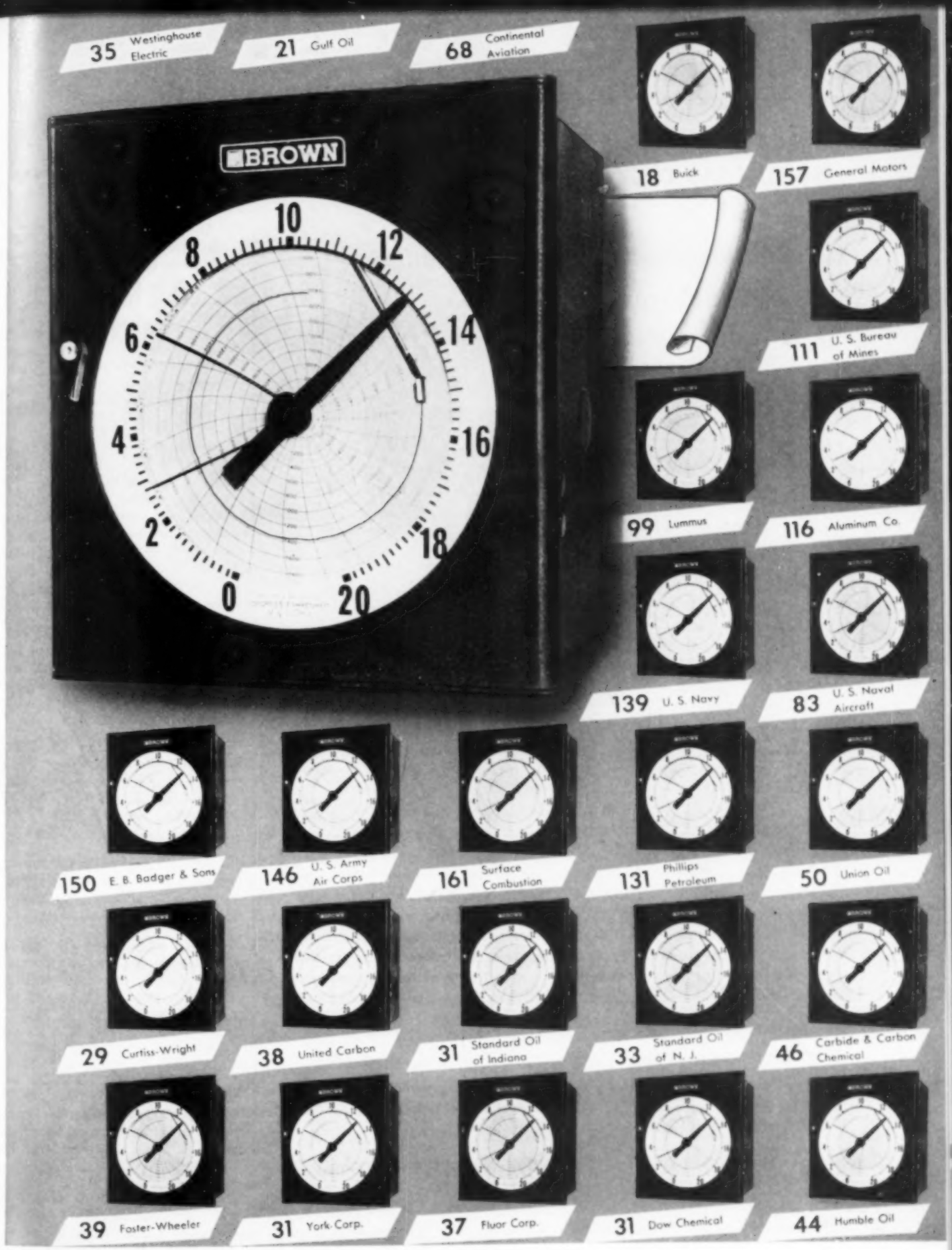

POTENTIOMETERS

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"ROCKWELL"
HARDNESS TESTER

Is Hardness Testing of most advantage to the Buyer or to the Seller of Raw Metal or Machine Parts?

LARGE companies employ the same sort of specifications, whether the department employing the material procures it from another department of the same organization or from outside sources. The user of the material sets specifications for what is essential. Any company desirous of continuing as the source of supply and desirous, as it must be, to keep down the loss of rejections must operate in a framework of cooperation with the buyer and should aim to function as if it were a department of the company to whom they supply.

The desire to have hardness testing sufficient and accurate must therefore be mutual.

Having kept hardness testing, by direct reading equipment, on a high plane of accuracy for 25 years, no one nowadays questions the merit of the "ROCKWELL" Tester.

The new models have greater speed, convenience and endurance also.

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Personals

ROBERT H. LACE is now associated with Ditto, Inc., Chicago, as quality control manager.

W. H. WHITE, formerly with Atlas Steels, Ltd., has established his own industrial distribution business in Hamilton, Ont., under the name of W. H. White Co.

ALFRED S. KOS has been promoted to chief division engineer, Nashville division, Consolidated Vultee Aircraft Corp., this now being the general manufacturing division of the company.

Rustless Iron and Steel Division, Baltimore, Md., announces the following appointments: STANLEY P. WATKINS as head of the newly established development engineering department and THOMAS L. MOORE as his assistant; FRANK BUFFO as manager and PETER B. KLINE as assistant manager of stainless bar and wire sales.

The University of Chicago announces the appointment of JOSEPH E. BURKE to the staff of the Institute for the Study of Metals. Mr. Burke was associated with the Los Alamos Laboratory.

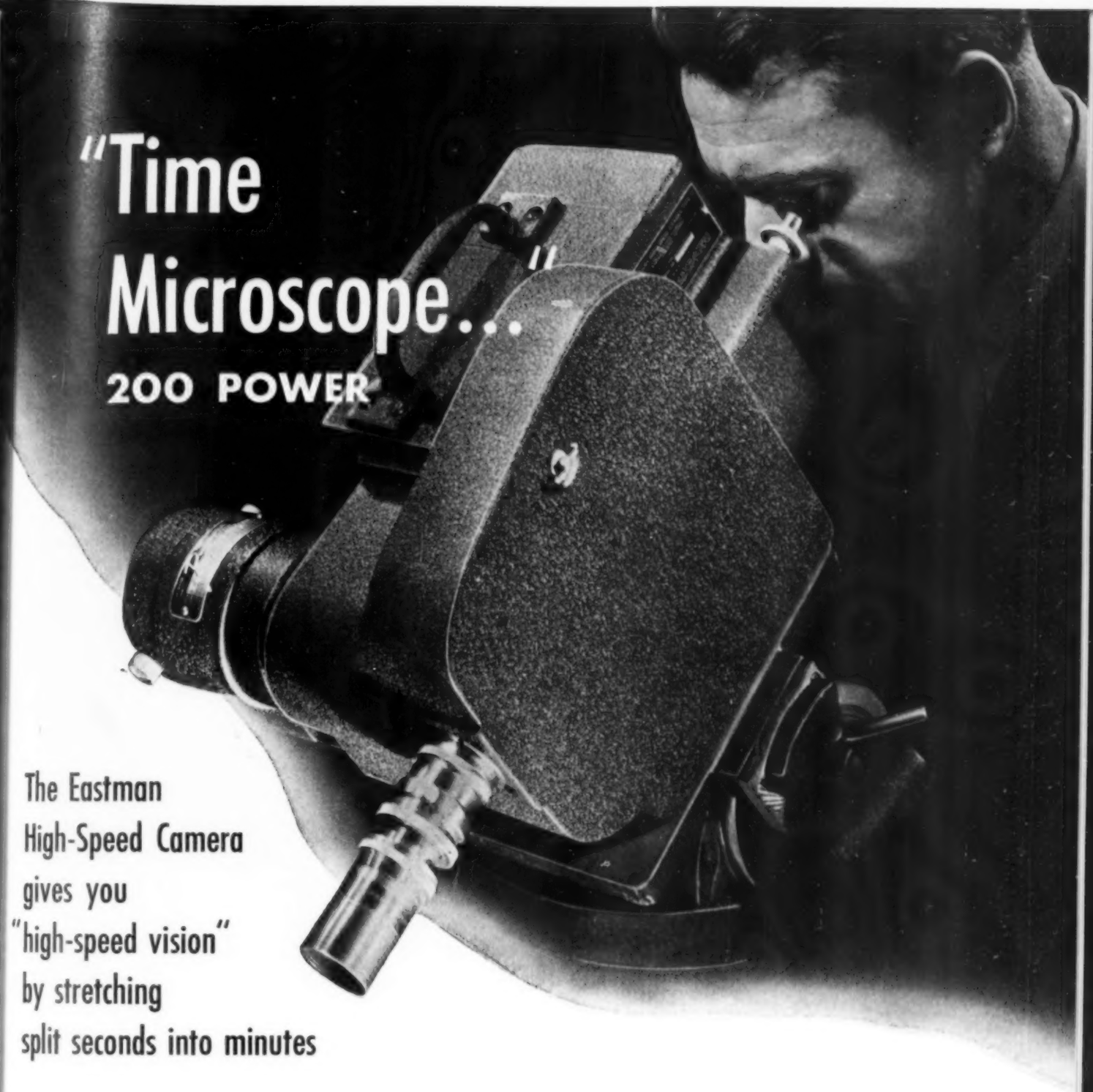
MORRIS D. UTLEY, formerly president of the National Gas Furnace Co., and the Industrial Furnace and Supply Co., has been appointed New England district sales manager of the Lithium Co.

CARL A. ZAPFFE announces the opening of his consulting office and research laboratory in Baltimore, Md., on Jan. 1, 1946.

JOHN H. OLSON has been transferred by the Aluminum Co. of America from the magnesium sand foundry in Cleveland to the research laboratories in New Kensington, Pa., where he is working as research metallurgist.

A. VARD DENNISON has joined the Newark Die Co., Newark, N. J., to take charge of the heat treating department. He was formerly associated with the B-M Heat Treating Co.

JOSEPH F. LIBSCH, formerly with the Springfield Armory, has accepted a teaching position on the staff of the department of metallurgical engineering at Lehigh University and will act as metallurgical consultant for the Lepel High Frequency Laboratories, Inc., New York.



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High-Speed Camera
gives you
"high-speed vision"
by stretching
split seconds into minutes

BY slowing to leisurely pace action far too fast for the human eye to register, the Eastman High-Speed Camera provides a direct approach to a variety of engineering problems.

It enables you to watch and study flame phenomena, movement of fluids, vibrations and chatter in machine elements, and many other types of motion too rapid for the eye to follow.

The Eastman High-Speed Camera gives you the visual facts you need. By taking motion pictures at 3,000 frames a second, then projecting these "high-speed" pictures, slowed down to 16 frames a second, you magnify "action time" nearly 200-fold, to the point at which you can see, analyze, measure.

New applications of the Eastman High-Speed Camera to industry's problems are constantly proving the value of this "Time Microscope."

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...another important function of photography

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WOULD MORE PRECISE TEMPERATURE CONTROL OF LIQUIDS OR GASES

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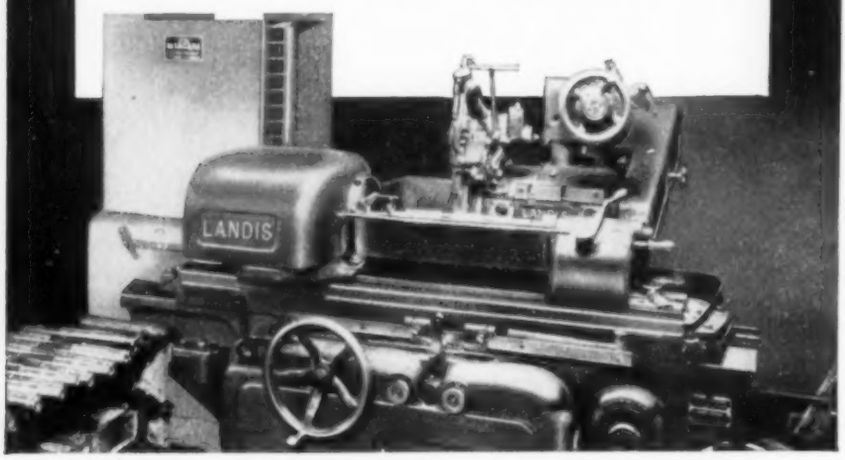

The NIAGARA AERO HEAT EXCHANGER holds the temperature of a liquid or gas within close limits. Many units have been installed because they provide a less expensive and less troublesome way of cooling fluids in an industrial process. But, after installation, users have discovered additional benefits of extra plant capacity, increased production and better quality production because the NIAGARA AERO HEAT EXCHANGER provided accuracy of temperature control.

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HUMIDIFYING • AIR ENGINEERING EQUIPMENT

Personals

Advanced Pressure Castings, Inc. announces that FRED J. TOBIAS, authority on die casting, will take charge of production and metallurgy for that company.

GEORGE JOHANNESSEN has enrolled at Purdue University where he will work for his M.S. degree in metallurgical engineering.

W. N. FARQUHAR has been transferred from the Spokane, Wash., plant of Alcoa to the Niagara Falls plant where he is works manager.

CHARLES S. MERCER has been transferred by Alcoa from the Mead works to the Boston office where he will be a sales engineer.

The Lithium Co. announces the appointment of THOMAS M. LACRONE, formerly metallurgical specialist with General Motors, as supervisor of research and experimental laboratory.

Battelle Memorial Institute announces that RICHARD J. LUND, formerly director of the miscellaneous minerals division of the War Production Board, has joined its staff.

Edward Valves, Inc. announces that E. B. POOL has been appointed to conduct a new type of valve research work. Mr. Pool was formerly mechanical and experimental engineer with Chrysler Corp.

Universal-Cyclops Steel Corp. announces the promotion of H. E. REPLOGLE to the position of manager of toolsteel sales development.

RAYMOND G. SPENCER, chairman of the metals and minerals research division of the Armour Research Foundation, has assumed his new post as director of the Washington University Foundation, St. Louis, Mo.

V. H. PATTERSON has been appointed general manager of the Progressive Foundry Works, Inc., Rochester, N. Y. He was formerly chief metallurgist of the Bausch & Lomb Optical Co.

After being released by the Navy, B. G. CONSTANTINE has been appointed Western Massachusetts, Vermont, Northeastern New York, and Connecticut representative of Sterling Alloys, Inc., Woburn, Mass.

What the OLSEN PENDULEVER WEIGHING SYSTEM means to you

in a Universal Testing Machine

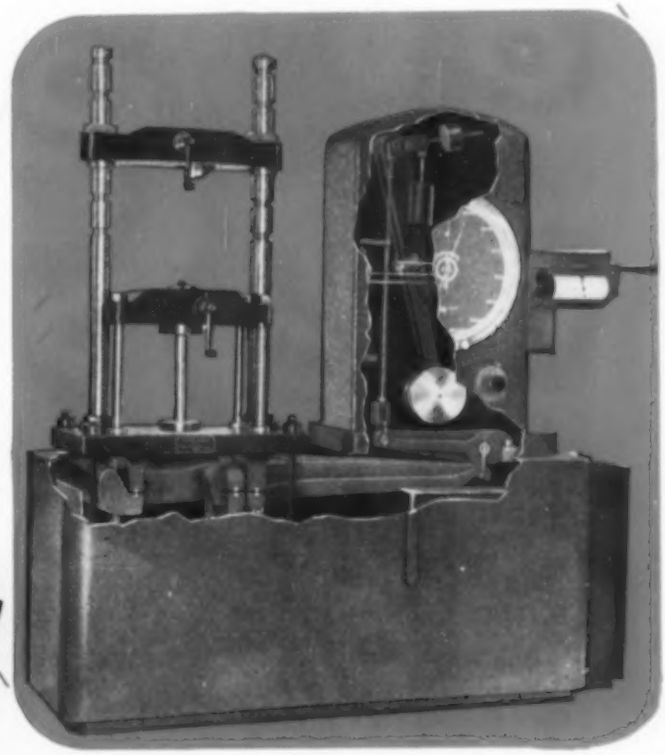
Simplicity No hydraulic or spring weighing mechanism used—just the simple lever and pendulum, employing the primary standards of distance and mass or weight—minimum number of moving parts—ease of reading with one-tenth of an inch between dial marks and the Olsen Multi-Masked Dial.

Accuracy Because the levers and pendulum involve only fundamental units of measurement, length x weight, the weight or load is transmitted by the most direct and sensitive means possible.

Reliability Temperature changes and mechanical variations, caused from outside sources, have no effect on the simple, automatically balanced and protected mechanism.

Economy Low maintenance costs, because of the simplicity and mechanical features—savings resulting from ease and speed of operation.

The lever weighing method is the most widely used for precision weighing, the reasons being obvious, for, if test results are to have any meaning, the correct load must be indicated accurately, with sensitivity and reliability. These are accomplished with the Olsen Universal Testing Machines, year-in and year-out, in all walks of industry.



For the complete story

on Olsen Universal Testing Machines write for Bulletin 30.

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Graphitization in Steam Lines*

THERE HAS BEEN much interest in the graphitization of low carbon and low carbon-molybdenum steels since the failure by graphitization of a steam pipe early in 1943.

Abnormal low carbon steel with the usual heat treatments graphitizes in a random arrangement at 850 to 1020° F. under reasonable stresses. The heat-affected zone of welds in this steel shows no more graphite than the unaffected metal. Normal low carbon steel under identical conditions has been found free from graphite after almost nine years at 1020° F. Carbon steel weld metal graphitizes in some cases but not in others.

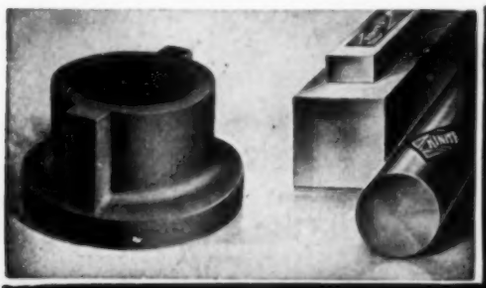
The presence of 0.5% molybdenum definitely improves the resistance to graphitization. Abnormal carbon-molybdenum steel shows only a slight amount of graphitization after 5½ years at 935 to 950° F. and after four years at 1050° F. if it has not been subjected to heating and cooling through the lower critical range by welding or upsetting. If abnormal carbon-molybdenum steel has been so heated, it graphitizes in service at temperatures as low as 915° F. and it can be graphitized in the laboratory within 1000 hr. at 1000° F. Repeated heating and cooling through the lower critical promotes graphitization in this steel, while increased rates of heating and cooling appear to favor the formation of the highly deleterious chain graphite. Prior transformation at high temperatures (i.e. slow cooling) seems to increase graphitization although it may occur following transformation at lower temperatures.

A stress of 10,000 psi. at 950° F. is less effective in inducing graphitization than heating and cooling through the lower critical temperature. A suitable preheating and stress relieving treatment for welds may effectively retard graphitization, or prevent it entirely. Slightly abnormal steel subjected to the heating and cooling cycle shows slight graphitization in service at 950 to 975° F. In the laboratory repeated heating and quenching has developed graphite after 3500 hr. at 1000° F. under 5000 psi. stress.

Normal carbon-molybdenum steel does not graphitize in service even under conditions where abnormal carbon-molybdenum steel graphitizes severely. Normal carbon-molybdenum steel subjected to repeated heating cycles in the laboratory has not developed graphite after 6000 hr. at 1000° F. Carbon-molybdenum weld metal has been found free from graphite even though it is abnormal. In general, carbon-molybdenum steel castings behave similarly to wrought material. However, it is noteworthy that several steel castings with abnormal structures have not been graphitized in service.

The McQuaid-Ehn test has proven to be a very satisfactory criterion of the graphitizing tendency of carbon and carbon-molybdenum steels. Steels to which 0.5 lb. per ton of aluminum or less has been added are normal and coarse grained in this test and also show little or no susceptibility toward graphitization. Steels to which 1.5 lb. per ton or more *(Cont. on p. 590)*

*Abstracted from "Graphitization of Low Carbon and Low Carbon-Molybdenum Steels", by H. J. Kerr and F. Eberle, *Welding Journal*, Feb. 1945, pp. 86s-122s; Discussion, *Welding Journal*, June 1945, pp. 350s-359s.



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THE STEEL WITHOUT AN EQUAL

KINITE is in the high carbon chrome alloy tool steel air hardening class.

An analysis all of its own . . . .
Its characteristics:

1. Increases production.
2. Reduces grinding and retooling time.
3. Resists wear and abrasion.
4. Excellent machinability.
5. Minimum distortion.
6. Fine heat treatability.
7. Immune to cracking during heat treatment.
8. In bar stock or castings.

KINITE alloy air hardening steel offers an unusual combination of features never before found in a steel of this type.

Pamphlets on request.

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faced 32 instead of 6 pieces per grind

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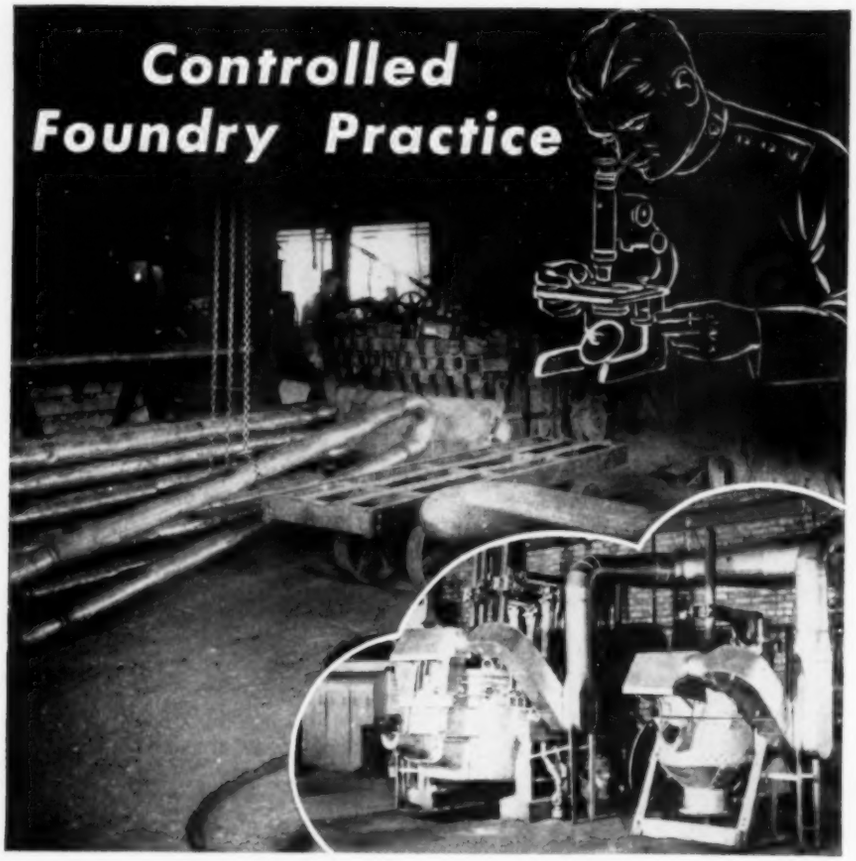
- Depth of cut . . . . . 3/8"
- Feed per revolution . . . 1/32"
- Cutting speed 235 ft. per minute

Cutting speed was also increased from 100 feet per minute to 235 feet per minute. No wonder the customer said, "A marvelous work value on this job."

If YOU have a cutting problem . . .

Call Firth-Sterling STEEL COMPANY

McKeesport, Pa.—New York, Hartford, Philadelphia, Pittsburgh, Cleveland, Dayton, Detroit, Chicago, Los Angeles



Another Reason For MICHIANA Uniformity of Quality

The ingredients of quality are often vague but in the MICHIANA foundry they are expressible in very concrete terms—improved material control, new casting techniques and flexible production methods to meet the requirements of peace-time activities. These qualities are necessary to the successful production of heat- and corrosion-resistant alloy castings that will withstand the most severe detailed tests.

In the MICHIANA foundry, every requirement from receipt of specifications to the finished casting receives the attention of skilled metallurgists, engineers and foundrymen. Every casting must pass the rigid controls and standards established by MICHIANA throughout a long history of successful applications of science, skill and know-how.

Over twenty-five years of practical experience has built up a wide and varied store of metallurgical knowledge, and original alloy casting information. This invaluable data is fully utilized so as to afford every user of MICHIANA castings the greatest advantage in longer heat-hour service, lower costs, maximum production and improved all-round performance.

MICHIANA
Heat-Resistant and
Corrosion-Resistant
ALLOY CASTINGS

MICHIANA PRODUCTS CORPORATION
Michigan City, Indiana

Illustrated Booklet 110 available upon request. Write today.

Graphitization

(Cont. from p. 588) of aluminum have been added are fine grained, abnormal and tend to graphitize. Steels to which intermediate amounts of aluminum have been added are of uncertain behavior as the McQuaid-Ehn case characteristics are mixed and cannot always be coordinated with the graphitization tendency.

It is recommended that a coarse-grained, normal carbon-molybdenum steel with the addition of 0.4 to 0.6% chromium be used for high temperature steam plant applications because of the greater carbide stability. In laboratory tests, weldments of such a steel showed no graphite after 6000 hr. at 1000° F.

In the discussion of this paper H. Weisberg pointed out that with so many factors involved there are bound to be some seemingly inconsistent service results. A slight amount of graphite has been found in the contact zone of a welded joint of a normal carbon-molybdenum steel. The only cure for badly graphitized joints appears to be replacement. A 1700° F. normalize after welding should avoid recurrence of graphitization but it is difficult to apply to joints; 4-hr. stress relief at 1300° F. may be sufficient.

H. W. McQuaid said that carbide coalescence is a preliminary step toward graphitization. Since abnormal steels are more susceptible, this fact would support Davenport and Bain's statement that abnormal steel has a high carbon diffusivity. Addition of aluminum to carbon and carbon-molybdenum steels with low manganese and sulphur over about 0.015% will result in a distinct tendency for the carbon to segregate away from certain grain boundaries where sulphides have concentrated. This would mean that the steel has localized areas where the carbides are difficultly soluble and therefore would tend to coalesce and finally graphitize.

H. A. Schwartz gave the steel foundryman's viewpoint that any tendency to limit the use of aluminum is a very serious matter. Low aluminum additions will give unsound castings as well as low ductility and impact resistance. Perhaps not enough attention has been paid to the silicon content of the steels. Conclusions reached mainly on the basis of wrought products should not be extended to castings without further work.

According to J. W. Bolton, aluminum deoxidized cast carbon-molybdenum *(Cont. on page 592)*

IT IS INDISPUTABLE!

.....that Da Vinci created Mona Lisa

.....that Driver-Harris created

Nichrome*

No. 70,265.

The United States of America

To all to whom these presents shall come:

This is to Certify That by the records of the UNITED STATES PATENT OFFICE it appears that Driver-Harris Wire Company, of Harrison, New Jersey, a corporation organized under the laws of the State of New Jersey, did, on the 19th day of April, 1908, duly file in said Office an application for REGISTRATION of a certain

TRADE-MARK

for Resistance Wires

and that the said TRADE-MARK, a statement setting forth, and a written declaration, duly verified, copies of which are filed herewith and to be duly complied with the requirements of the law and said rules made and provided, and until the regulations prescribed by the COMMISSIONER OF PATENTS.

And upon due examination thereof, it appearing that the said applicant is entitled to registration of said TRADE-MARK under the law, the said TRADE-MARK has been duly registered to Driver-Harris Wire Company, and the same is recorded in the UNITED STATES PATENT OFFICE, this 11th day of August, 1908.

The said TRADE-MARK shall remain in force for TWENTY YEARS, unless sooner terminated by law.

In testimony whereof I have hereunto set my hand and caused the seal of the PATENT OFFICE to be affixed at the City of Washington, this eleventh day of August in the year of our Lord one thousand nine hundred and eight and of the Independence of the United States the one hundred and thirty-third.

Acting Commissioner of Patents.

TRADE-MARK.

REGISTERED AUG. 11, 1908.

No. 70,265.

DRIVER-HARRIS WIRE COMPANY.

RESISTANCE WIRE.

APPLICATION FILED APR. 19, 1908.

NICHROME

SPECIFICATION

Driver-Harris Wire Company

By its Attorneys

Baker, Simmons & Masterson

Down thru the ages the inscrutable countenance of Mona Lisa has been irrefutably attributed to and associated with Leonardo Da Vinci. Authenticated records prove conclusively that he was the creator of this masterpiece.

Likewise, the indisputable ownership of the trade-mark NICHROME for Resistance Wire was established by this duly authorized document granted to the Driver-Harris Company on August 11th, 1908. Subsequent registrations cover other product applications. Thus NICHROME is the registered trade-mark belonging solely and wholly to the Driver-Harris Company.

NICHROME is also the symbol of service that has for 38 years identified the *world's foremost heat and corrosion resistant alloy* – the time-tested standard by which other alloys are measured. Although there are other excellent nickel-chromium combinations there is only *one* NICHROME . . . and it is made *only* by Driver-Harris.

*Nichrome is made only by

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COMPANY

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Instantly

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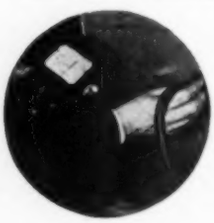
This instantaneous direct reading air velocity meter measures air speed in feet per minute. There are no calculations, no timing, no conversion tables; its use is so simple that anyone can take accurate measurements with the Velometer. Extension jets permit correct readings in many locations that would be difficult or impossible to reach with other means of measurement.

Keep exhaust equipment working efficiently by regular checks for draft, leaks, blower operations, etc., with the Alnor Velometer. You can get accurate information on performance with a few minutes' inspection at regular intervals.

The Velometer is made in several standard ranges from 20 fpm to 6000 fpm and up to 3 inches static or total pressure. Special ranges available as low as 10 fpm and up to 25000 fpm velocity and 20 inches pressure. Write for Velometer bulletins.

Velometer used for positive static pressure readings



ILLINOIS TESTING LABORATORIES, INC.
420 North La Salle Street
Chicago 10, Illinois

Graphitization

(Cont. from page 590) steels are more susceptible to graphitization than silicon deoxidized cast steel. However, at least one cast alloy steel (WC 4) has a high resistance to graphitization even when deoxidized with aluminum.

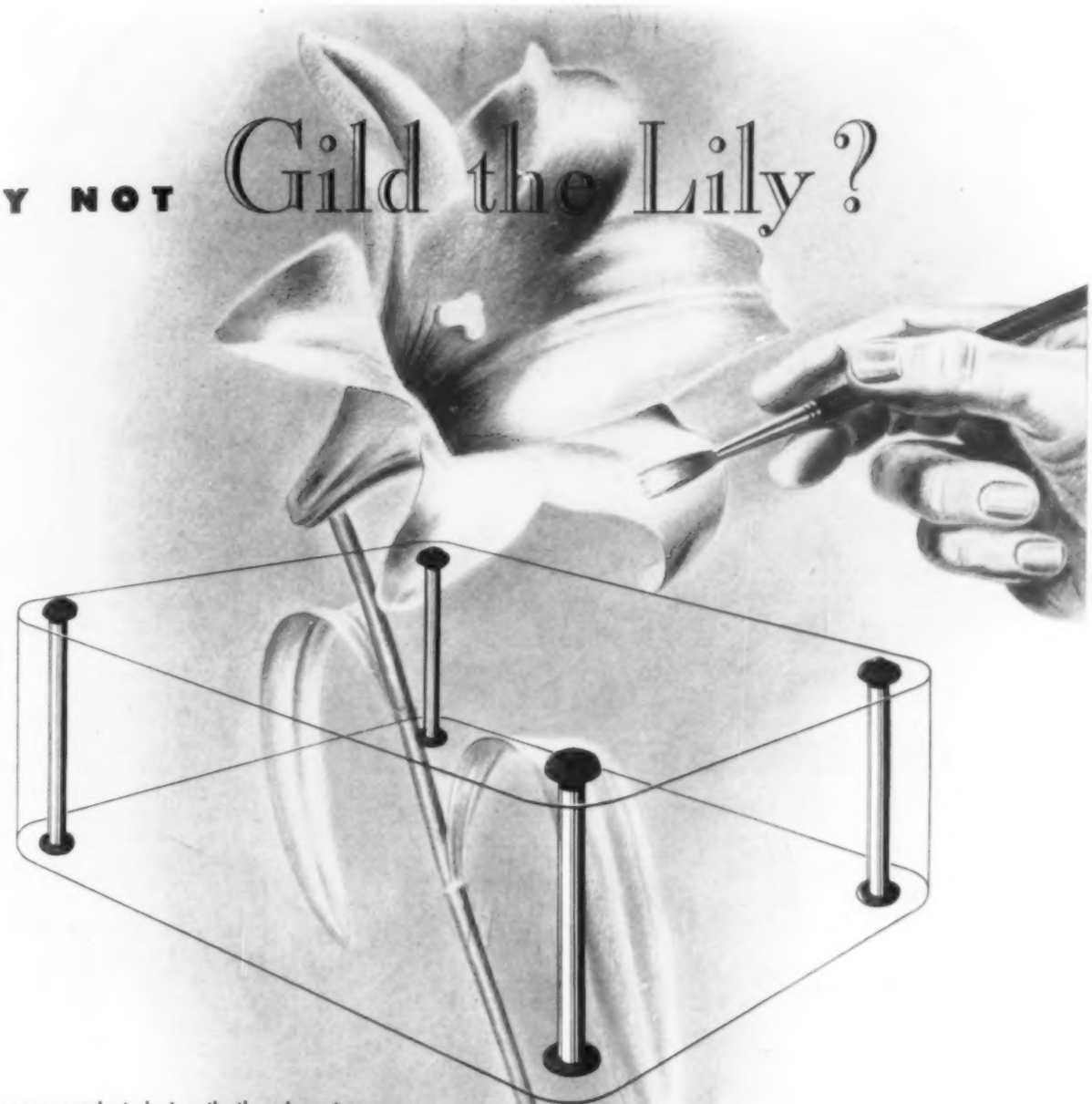
F. B. Foley suggested that the graphitization is caused by the metallic aluminum dissolved in the ferrite. The cure for carbide instability is not to be found necessarily in the elimination of aluminum for deoxidation. Steel makers can control within narrow limits the characteristics of steel affected by aluminum deoxidation, and undoubtedly can control this new variable when the factors involved are more clearly developed. It is possible that fluctuations in service temperature may be a factor.

W. R. Farnsworth said that carbon-molybdenum and carbon-chromium-molybdenum steels with a normal coarse grain have been produced satisfactorily. Particular attention must be paid to the scrap used, the condition of the slag and the timing of the deoxidation. The use of aluminum must not be eliminated entirely.

In the authors' closure it was brought out that heat treatment may also affect the susceptibility to graphitization. Samples from an abnormal carbon-molybdenum steel were given various treatments and then held 1500 hr. at 1000° F. Air cooling from 2200° F. gave the maximum resistance to graphitization which was not affected by 50% cold work after heat treatment. Air cooling from 1650° F. also rendered the steel resistant but 50% cold work caused the steel to graphitize slightly. Furnace cooling from 1650° F. did not induce graphitization but a noticeable amount of graphite was formed after 50% cold working. Furnace cooling from 2200° F. made the steel sensitive to graphitization; this sensitivity was increased by 50% cold work after heat treatment. Reheating to 1400° F. followed by slow cooling caused a slight amount of graphitization in steel previously air cooled or furnace cooled from 1650 or 2200° F. Reheating to 1400° F. and quenching promoted graphitization more than any other treatment except those followed by cold work.

Cold deformation promoted graphitization in almost all conditions. Chain graphite was formed in the weld-heat-affected zone of samples of the same steel which had been repeatedly arc welded.

WHY NOT Gild the Lily?



You have a product design that's a beauty . . .
to be produced in plastic, leather, wood or metal.
It has to be held together in some way, so why not make Alcoa Aluminum fastening devices part of the design?
Alcoa Aluminum can be given any number of attractive and unusual finishes and colors which give added eye appeal.
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Testing Machines are designed for accuracy of load application and simplicity of operation. Manufacturers of machines for all types of testing problems in the production engineering field.

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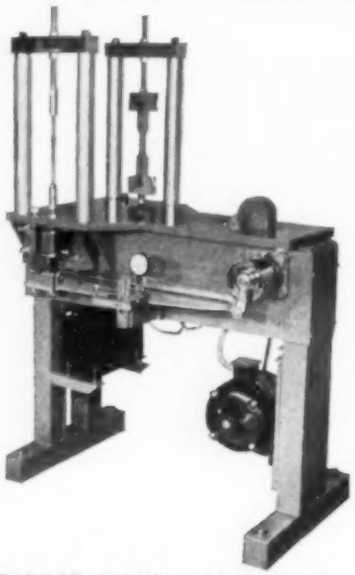

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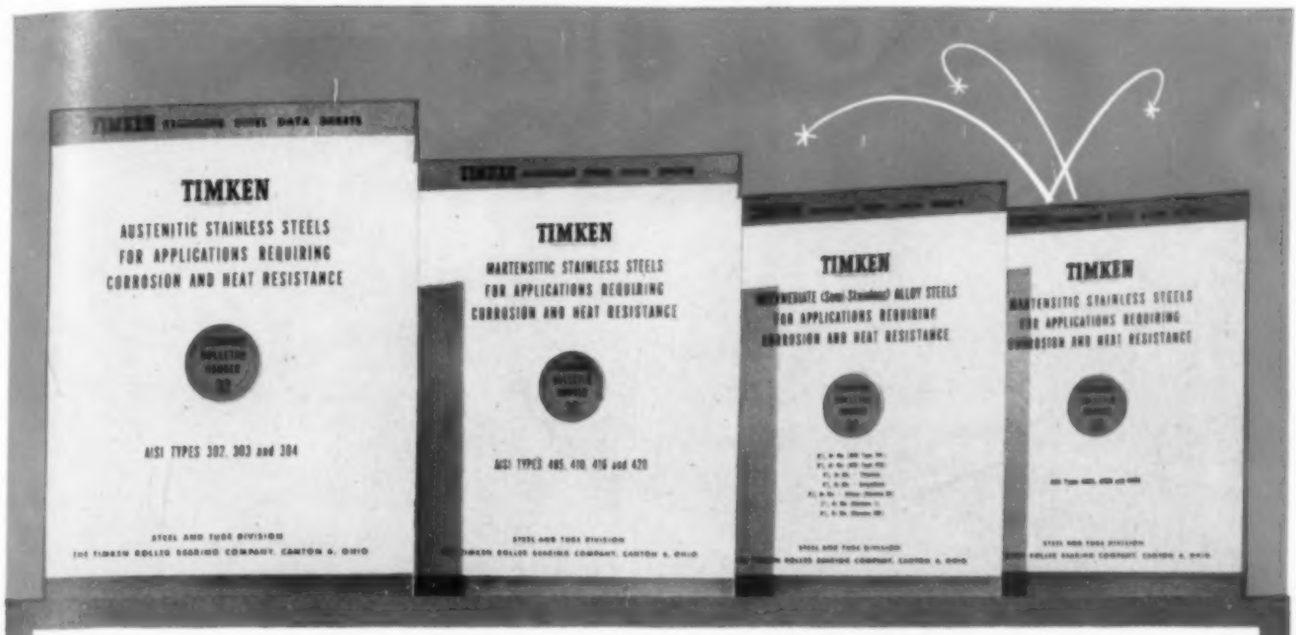
German Corrosion Research

A BROAD SURVEY of the whole field of corrosion and corrosion protection is given by the Gesellschaft fuer Korrosionforschung und Werkstoffschutz in a series of papers by German authorities on various aspects of the problem.* Recent research on corrosion of iron and steel was discussed by F. Eisenstecken. The author emphasizes the care necessary in interpreting the results of short-term corrosion tests against long-term tests. For example, it has been definitely established by careful, long-time investigations that the corrosion resistance of steel increases with increasing phosphorus content; this is in disagreement with the results obtained from short-term tests.

W. Machu (a recognized German authority on phosphatizing) presented a paper on the electrochemical pore test method for the quantitative examination of protective finishes, with special reference to phosphate coatings. Porosity is the dominant factor governing the efficiency of any protective finish and the quantitative determination of this property is essential, both at the beginning and also at the end of the coating process. The effect of operational modifications may thus be followed, particularly as regards the preliminary preparation of the metal surface before coating and the composition of the base metal. In poorly operated phosphatizing baths, the porosity value may rise to over 60%; with a well controlled bath, the porosity value may be as low as 0.1%.

A paper presented by E. Baerlecken discussed heat and corrosion resisting steels developed for military operations. The German problem has been to limit the amount of chromium in steels of this type. For heat resisting steels, chromium has been partially replaced by silicon and aluminum. For example, 10% Cr has been replaced by either 2.5% Si or 3.5% Al. Likewise the austenitic Cr-Mn steels have tended to replace the austenitic Cr-Ni steels. Scarce molybdenum, which has the effect of markedly increasing the mechanical strength at elevated temperatures, has been replaced completely by vanadium and titanium. There has also been a trend toward the use of the lower alloyed ferritic Cr steels; in these it is not possible to *(Cont. on p. 596)*

*Korrosion und Metallschutz, v. 20, no. 1, January 1944, pp. 63-76.



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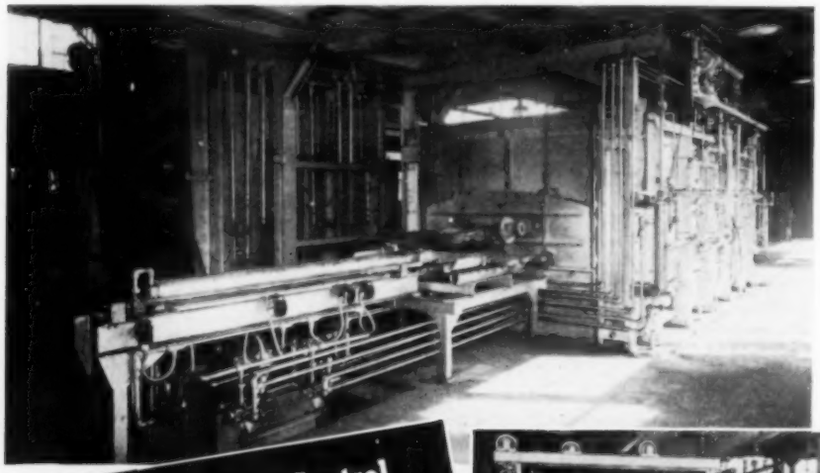

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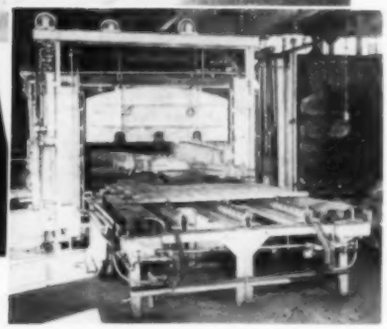

Discharge end of gas-fired, pusher-tray furnace showing Misco cast alloy, grid type tray emerging from furnace. Above — hydraulic pusher and casting at charging end just before door is raised and work movement into furnace begins.

ROCKWELL *Pusher-Tray* FURNACE

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This predictable, controlled annealing method produces metal of uniform grain size, eliminates hard spots due to uneven heating and cuts down subsequent machining time appreciably. Instead of supervision of an experienced heat treater, common labor for loading and removing castings is sufficient.

The pusher-tray furnace described here is but one of many of this type built by Rockwell for annealing, hardening and drawing metal products of all kinds, sizes, shapes and quantity to improve the product, process and balance sheet.

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Bulletin No. 423 tells how.

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German Corrosion Research

(Cont. from p. 594) substitute other elements for the chromium. It was often possible, however, to use the ferritic Cr steels or the austenitic Cr-Mn steels in place of the austenitic Cr-Ni steels. For instance, the ferritic Cr steels have been used in the chemical industry, since, with suitable alloying additions, they satisfy all the fabrication requirements imposed by welding. Finally, composite clad metals go far to solve the shortages existing in Germany. The technique of "inchroming", or chromium cementation, in which chromium is diffused into the base metal, would appear to be useful, since the surface has a high resistance to corrosion by many chemicals.

Diffusion of chromium into a steel surface was the subject of a paper by H. Bennek.★ A volatile chromium compound is employed (usually chromium chloride) and the process is carried out in an electric furnace at about 2000° F. Carbon in the steel tends to limit the chromium diffusion. It is possible to obtain a chromized case from a chromium-vanadium salt bath six to seven times as thick as one produced from a bath in which only chromium chloride is present. The author states that such chromized parts have a higher corrosion resistance than 18-8 or 17% Cr steel.

The application of this process was also discussed by H. Hougardy and P. Schierhold. The normal layer obtained with this process (0.004 in. thick) is soft — no harder than the base steel itself. The process is being developed to produce layers 0.016 in. thick. Consequently, applications involving wear, erosion or high surface loading are out of the question. Subsequent working of the coating by polishing or turning is also unwise. It is found specially advantageous to chromize compact parts, such as screws, nuts, spindles, and valves, the surface of which is small in relation to the mass. Chromizing of large components or those of complicated shape, especially those which enclose a large hollow space, is generally impossible. During the chromizing process, dimensional changes occur on the order of 0.001 to 0.004 in. on the diameter. In these authors' experience, the heat and corrosion resistance of the treated component is comparable to that of a good class of Cr-Ni steel.

★*Korrosion und Metallschutz*, v. 20, no. 2, February 1944, pp. 107-113.

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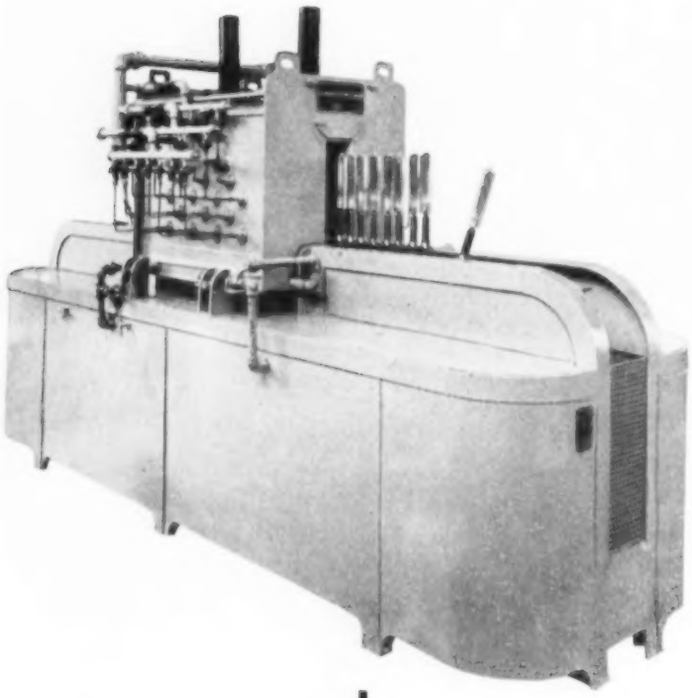

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Superheating Magnesium Alloys*

IT IS WELL KNOWN that aluminum-type magnesium alloys should be superheated by holding an appreciable time at a temperature over 1550° F. and then quickly cooled to about 1325 to 1450° F. before casting to produce grain refinement and appreciably better mechanical properties.

The grain size determined by polishing and etching solution treated test bars precipitation hardened 16 hr. at 390° F. agreed closely with the measurements on as-cast specimens, polished, etched, and squeezed in a vise to form a cold-worked structure with many twins and a clear crystal identification. Most of the grain size measurements were made on solution treated specimens.

The effect of time and temperature of superheating and of raw materials was determined on 3% aluminum binary alloys. The alloys made from virgin materials showed rather better results than the remelted material, both in response to superheating and in tensile properties. Superheating for 45 and 90 min. at 1650° F. gave the usual grain refinement. However, heats superheated for 30 min. at 1920° F. had a coarse grain size equal to unsuperheated melts and a 0.1% proof stress — even lower than the unsuperheated material.

Heats of a 6% aluminum alloy were made to determine the effect of varying times (up to 2½ hr.) at 1650° F. and varying superheating temperatures. A clear improvement in properties after superheating at 1650° F. was again apparent. The whole of the improvement was obtained by heating to 1650° F. without any holding time at the superheating temperature. Holding times up to 30 min. had little effect but longer holding times caused a slight but definite deterioration in properties and grain size. A comparatively coarse grain size and poor properties resulted from 30 min. at 1920° F. If melts previously superheated for 45 min. at 1650° F. were held 1 hr. at 1290° F. and then reheated to 1400° F. before casting, the grain refinement was largely lost. At 1560° F., there was little grain refinement unless the melt was held *(Cont. on p. 600)*

*Abstracted from "Superheating in Magnesium-Base Alloys", by F. A. Fox and E. Lardner, *Engineering*, v. 159, June 1, 1945, pp. 438-440; June 15, 1945, pp. 478-480.

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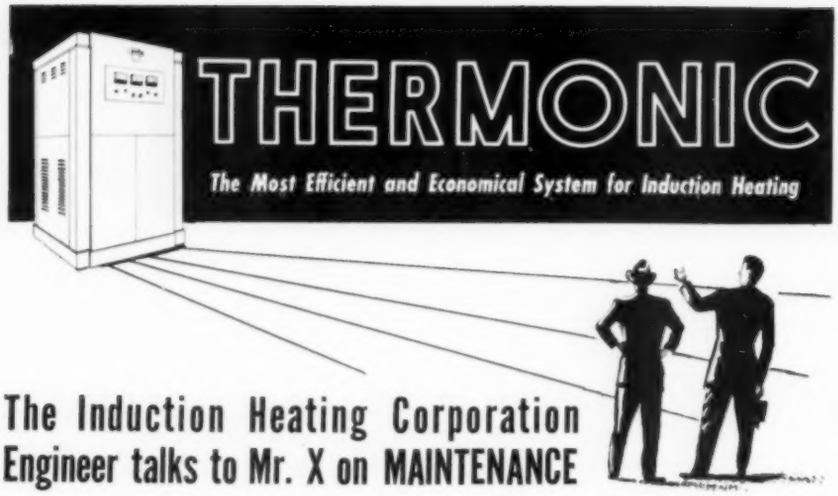

The Induction Heating Corporation Engineer talks to Mr. X on MAINTENANCE

MR. X . . . . I have no doubt, Mr. Engineer, that THERMONIC Induction Heating equipment will give me excellent results in my heat-treating problem, but can I install it in my production line and expect the same degree of performance as with other machine tools? My milling machines and lathes are easy enough to maintain, but does this equipment of yours present any special maintenance problems?

ENGINEER . . . . On the contrary, Mr. X. Your shop electrician can maintain this equipment. THERMONIC Generators are powered by two types of electronic tubes: oscillator tubes and rectifier tubes. As a safety measure, the equipment is run considerably under the power rating of these tubes. The oscillators are exactly the same tubes used in radio-broadcasting transmitters and our experience shows them to have an average service life industrially of approximately 4,000 to 6,000 hours. Pre-war tubes were even better than these and even superior performance can now be expected. I don't think you've ever heard of a radio station going off the air from tube failure. Certainly such a performance should be an assurance to you.

MR. X . . . . But how about the rectifier tubes? Do they last as long as the oscillators?

ENGINEER . . . . Even longer! Rectifiers are even more rugged than oscillators and have an average service life of around 6,000 to 8,000 hours. And it's a matter of minutes to replace either of these tubes. It may interest you to know that the price of both oscillators and rectifiers has been greatly reduced in the past year or so, and we believe the Induction Heating Corporation is largely responsible for this due to the thousands of such tubes we use. On the basis of the average service-life estimate we have made, the cost of tube replacement is only 5 to 7½ cents per hour of operation, depending on operating conditions.

MR. X . . . . Are these tubes the only parts in THERMONIC units which must be replaced?

ENGINEER . . . . Absolutely, Mr. X. In a recent survey of over five-hundred THERMONIC units in service over two years, the record of service calls shows only one every 25 months, including calls of all types. We feel very proud of this record and are willing to match it against that of any other type of machine tool.

MR. X . . . . That's sure a good performance record. How do you account for it?

ENGINEER . . . . That's because of the extensive tests which we make on all units before they are accepted for shipment. Our test department operates every unit at full load continuously for such a period of time that the temperature curves at various points throughout the unit become constant. If any "hot spots" occur, the units are rejected and returned immediately to the production department for further investigation. And what's more, high potential tests specified by the American Standards Association are conducted on all components of THERMONIC Generators. We realize that such tests are expensive, but they are well worth while in the service rendered to our customers. Incidentally, there are no moving parts in THERMONIC Generators except for a small blower which cools the rectifier tubes. This point alone eliminates many of the maintenance problems.

MR. X . . . . Then you believe that this equipment can be installed on our production line and maintained by our shop electricians?

ENGINEER . . . . I certainly do and offer you the experience of close to a thousand installations to prove this point. Remember, THERMONIC Induction Heating equipment is a machine tool which can go right into your production line, and like other machine tools, it will stand up under continuous heavy service.

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Superheated Magnesium

(Cont. from p. 598) 5 min. or longer. However, melts held 4 hr. had a tendency toward grain coarsening. There was considerable grain refinement merely by heating to 1650° F. A slight further improvement was noticed after 5 min. holding but prolongation of the superheating time caused a small but definite increase in the grain size. At 1740° F., the best results were obtained merely by heating to temperature without holding. If the melt was held, there was a marked increase in grain size. In general, for a given time, the grain size was larger and the tensile properties lower for 1740° F. than for 1650° F. or 1560° F.

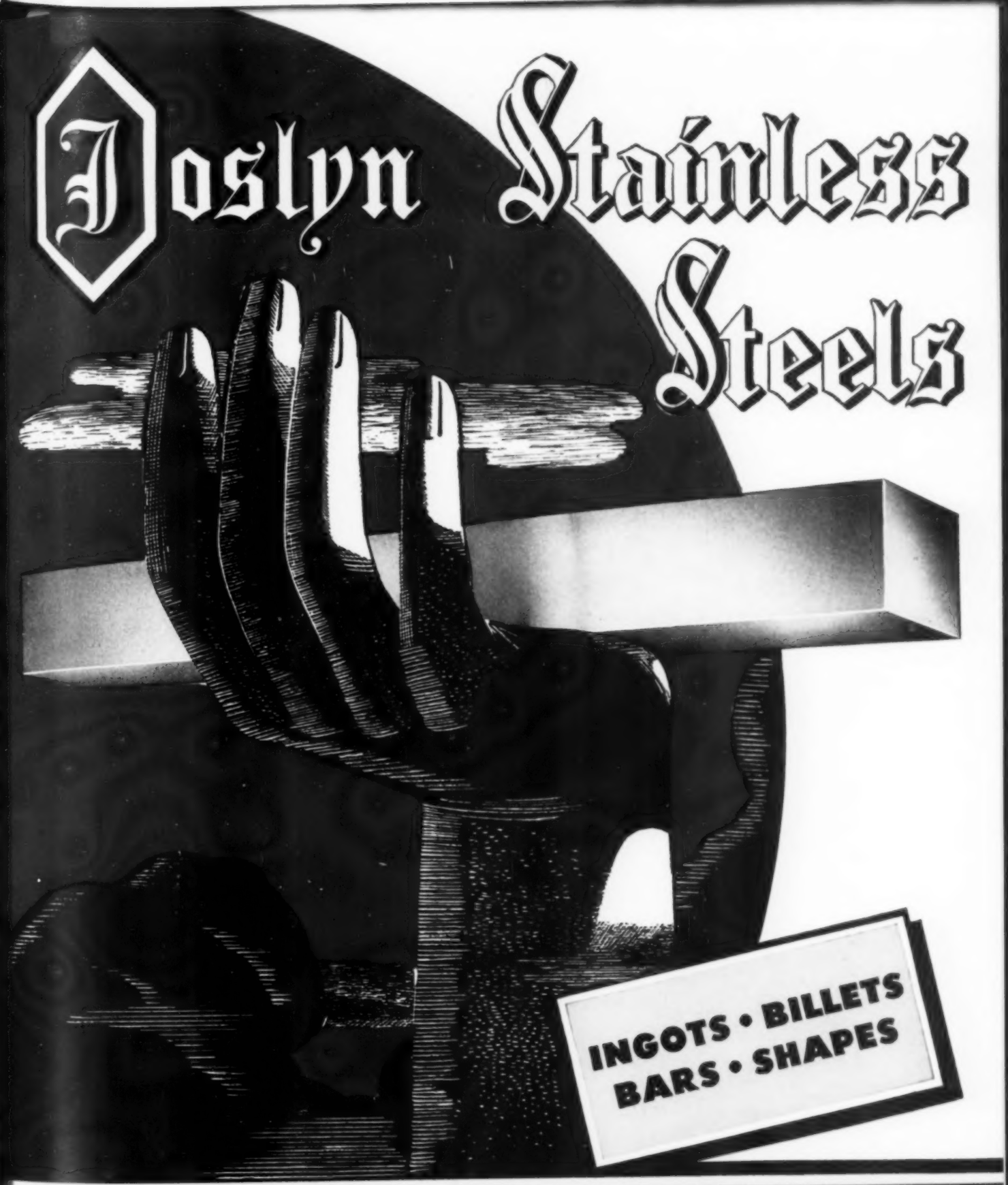
A complex commercial alloy (AZ 91 — DTD 136 A) with 9.6% aluminum was superheated up to 4 hr. at 1560, 1650, and 1740° F. Heating to 1560° F. gave some grain refinement and considerable improvement in tensile properties although the same treatment had been ineffective for the 6% aluminum alloy. An increase in holding time up to 2 hr. gave a slight improvement but 4 hr. caused a coarser grain size and poorer properties. At 1650° F., the finest grain size was obtained by holding 10 min.; longer times gave a coarser grain size and lower tensile properties. Superheating at 1740° F. gave a markedly coarser grain size and lower tensile properties than any of the corresponding specimens at 1560 or 1650° F. Prolonged holding again increased the grain size.

In general, there appears to be little effect of superheating on the grain size of binary alloys with silver, calcium, cadmium, lead, manganese or zinc or with a commercial 1.5% manganese alloy (DTD 140 A; Elektron AM 503). However, additions of beryllium or zirconium to magnesium alloys with aluminum caused the formation of a coarse grain even after the melt had been superheated.

In general, unsuperheated DTD 59 A (Elektron A) had an irregular dendritic form. The dendrites were marked, but not strongly, by semi-continuous lines of beta phase and many isolated beta pools which tended to outline the dendrite arms. The grain size was coarse and non-uniform. An increased rate of solidification (smaller sections) formed smaller, more uniform and better marked dendrites.

The main microscopic characteristic of the superheated material was the absence *(Cont. on p. 602)*

Joslyn Stainless Steels



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★ Quench operation entirely mechanized.

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Superheated Magnesium

(Cont. from p. 600) of a dendritic formation. The grain size was uniform, small and more or less regular in shape. The beta was less continuous and was found only in the grain boundaries. The rate of cooling seemed to have a less marked effect on the superheated material than on unsuperheated material. With the superheated alloy, the difference was mainly one of scale although with very slow cooling (3 in. dia.) there was some evidence of a slightly declining influence of the superheating with a less regular structure, some signs of dendrites and beta particles in the dendritic interstices.

The grain size of the superheated material increased relatively slowly as the section increased to 3 in. dia. With the unsuperheated material, increasing section caused a rapid increase in the grain size. The effect of the superheating in preventing the formation of coarse grains in heavy sections is very marked.

There was little difference between superheated and unsuperheated material cast directly into cold water. The superheated material had a somewhat coarser grain than the unsuperheated material but it was more uniform.

It has been stated that if any melt which has been superheated is vigorously stirred before casting, all of the grain refining effect produced by the superheating will be lost. Tests made on melts of 8% aluminum, 0.3% zinc, 0.25% manganese material showed a 3-min. stirring had no influence upon the refinement caused by superheating.

The phenomenon of grain refinement of magnesium-aluminum alloys by superheating is almost certainly a question of nucleation. Any theory put forward to explain the effect of superheating must cover the following points: *(a)* The grain refinement effect is peculiar to magnesium alloys with aluminum. The superheating effects vary somewhat with the aluminum content; *(b)* the grain refinement persists on remelting; *(c)* the grain refinement is lost if the superheated melt is allowed to stand for a sufficient length of time at a temperature just above the melting point; *(d)* the grain refinement effect of superheating is lost if certain elements such as beryllium and zirconium are added; *(e)* the grain refinement is lost to some extent if some maximum temperature in the region of

(Continued on page 604)

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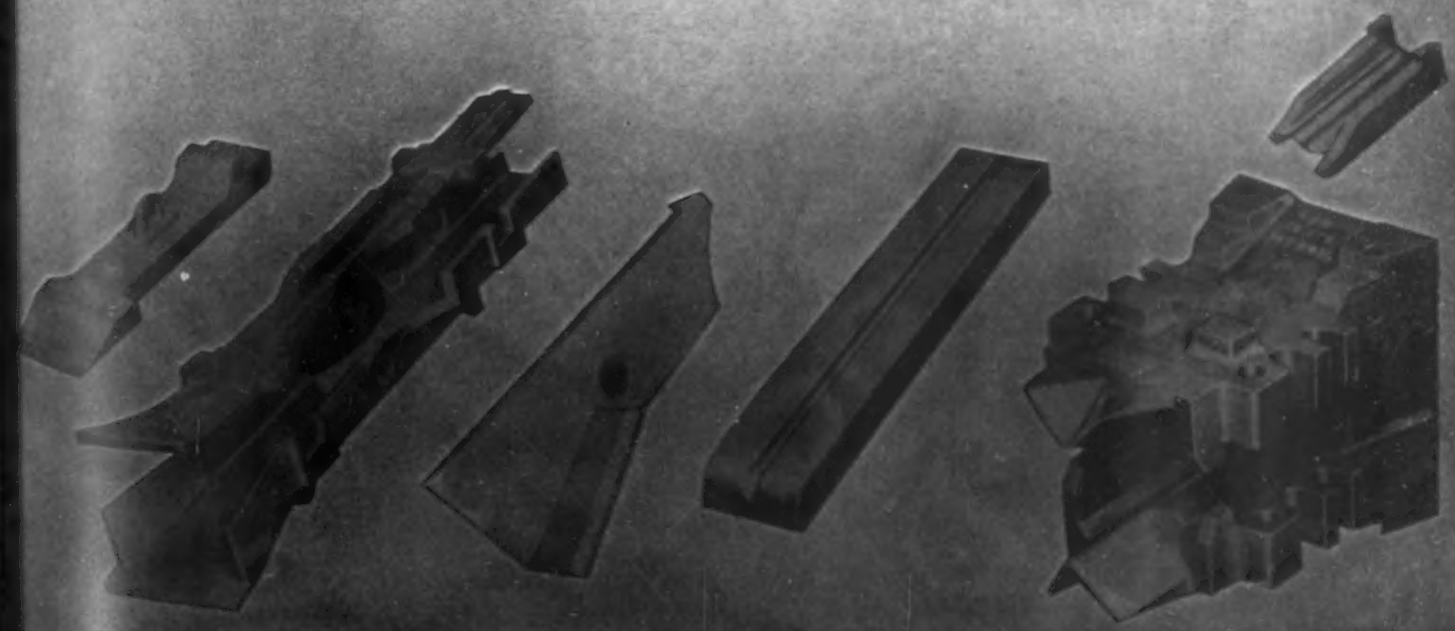

YOUNGSTOWN ALLOY CASTING CORPORATION

Youngstown, Ohio

Superheated Magnesium

(Continued from page 602)

1650° F. is exceeded or if the melt is held at more normal superheating temperatures for an excessively long time. The temperature effect seems to be of greater importance than the time effect.

No simple nucleation theory has been formulated which explains adequately all these facts. There are two general explanations: *(a)* The grain refinement by superheating is due to the removal of all kindred nuclei with consequent grain refinement by supercooling; *(b)* the grain refinement is due to the production of clouds of foreign nuclei with supercooling not involved. Previous observations were that superheated melts did not undergo supercooling while unsuperheated melts did tend to. This would favor the foreign nuclei theory but the supercooling was very slight.

Our knowledge of the mechanism is still limited. The plain fact remains that DTD 289 magnesium alloy will have a tensile strength of 38,000 psi. if superheated and 29,100 psi. if not.

Friction Tests on Bearing Alloys*

ALLOYS WITH a hard matrix (copper) in which are dispersed particles of a soft metal (lead) theoretically function by the extrusion and smearing of the soft phase over the hard matrix to provide metallic film lubrication. However, this explanation is not applicable to alloys such as the white metals which have hard crystals embedded in a relatively soft matrix.

The friction testing apparatus had an upper surface in the form of a hemispherical slider while the lower surface was a flat plate which was driven forward at a uniform rate. Each combination was tested in two ways, once with one metal used as the upper curved surface and then with this metal as the lower surface.

A special microhardness apparatus having a finely polished pyramidal diamond under a load of 0.3 to 1 g. was very satisfactory.

Vickers macroscopic hardness for pure lead was 4, for the lead bearing alloy 21, and for the lead matrix alloy 18. The microhardness in equivalent Vickers units was as follows: For the lead bearing alloy, 17 in the matrix and 110 in the cuboids; for the lead matrix alloy, 18 in both the lead-rich solid solution and the duplex lead-tin-antimony eutectic.

The first set of tests was made on two alloys — a lead bearing alloy with 15.0% antimony, 0.5% copper, 6.0% tin, 78.5% lead; and an alloy designed to reproduce the properties of the matrix of the first alloy with 10% antimony, no copper, 3% tin, 87% lead. Table I on page 606 shows the maximum coefficient of friction at room temperature for steel and lead alloys.

These results show the similarity between the properties of the lead-base bearing alloy and those of the lead-base matrix alloy. The friction when clean and lubricated, the behavior with respect to temperature and wear, the types of track formed and *(Cont. on p. 606)*

*Abstracted from "The Frictional Properties of Some White Metal Bearing Alloys: the Role of the Matrix and the Hard Particles", by D. Tabor, *Journal of Applied Physics*, v. 16, June 1945, pp. 325-337.

THERE'S A NEW PLUS IN THEIR PUNCH

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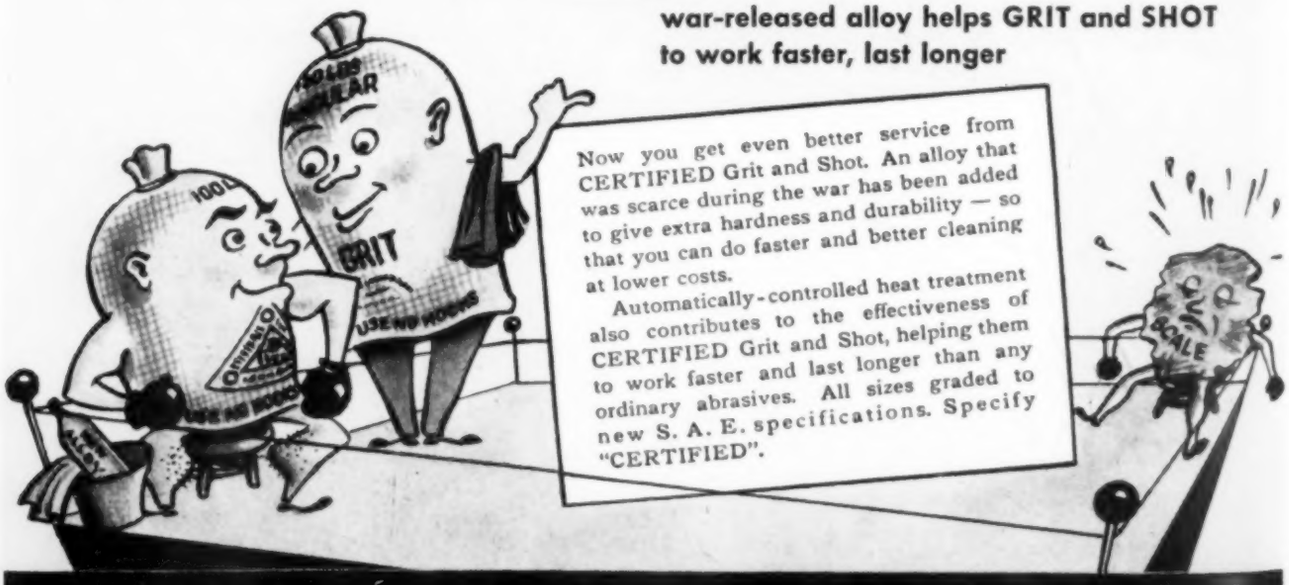

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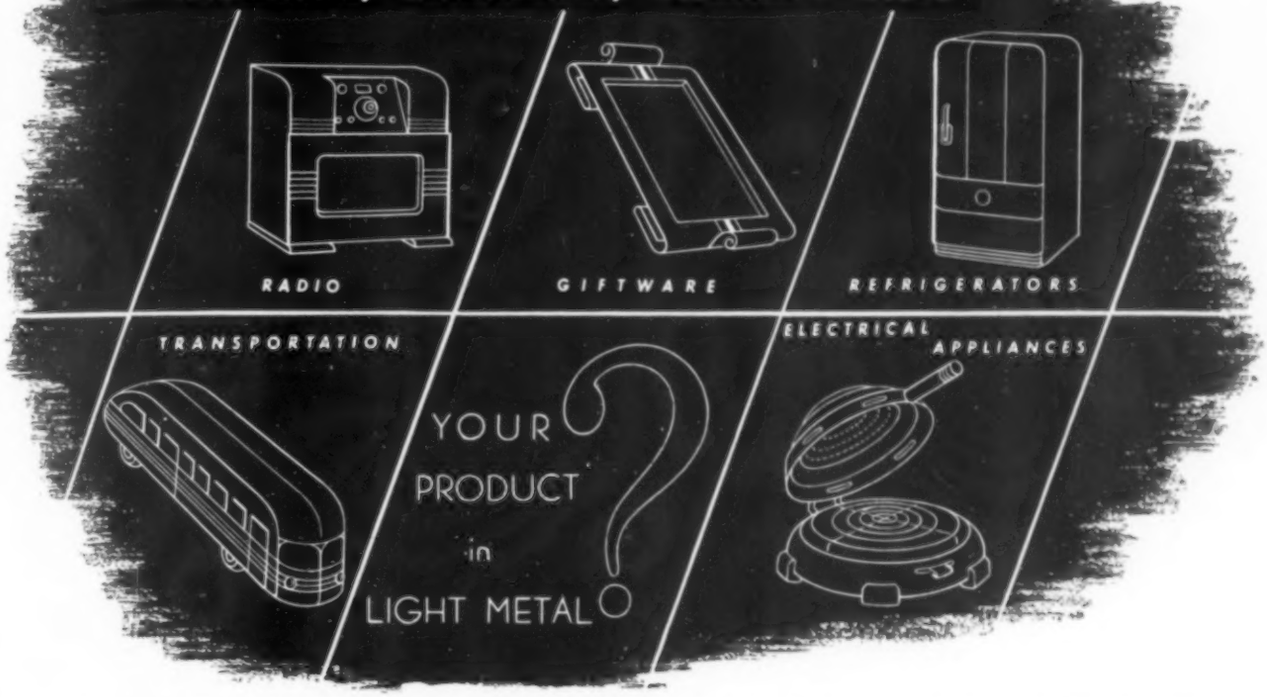

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Bearing Alloys

(Cont. from p. 604) the nature of the wear are all markedly alike. These properties are also similar to those of pure lead except that in general the friction of the alloys is less than that of pure lead. It is evident, therefore, that the behavior of bearing alloys is similar to that of materials containing no hard particles. In general, the friction of the lead-base bearing alloy is less by a few per cent than that of the matrix alloy. However, the difference is small and the hard crystallites do not greatly affect the intrinsic frictional or wear properties of bearing alloys. It is suggested that the frictional behavior of lead-base bearing alloys is determined essentially by the properties of the matrix material of the alloys, although in practical running operations there may be other properties which determine the suitability of the alloy for use in bearings.

Similar tests were made on a tin bearing alloy with 6.5% antimony, 4.2% copper, 0.1% nickel and 89.2% tin and a tin matrix alloy with 7% antimony, 0.4% copper, no nickel and balance tin, with the results shown in Table II, below.

For unlubricated surfaces, the frictional properties of the tin-base bearing alloy are similar to those of the tin-base matrix alloy, both at room temperature and at temperatures up to 390° F. The friction is not very much less than that of pure tin. With lubricated surfaces at room temperature, the friction is also similar but there is considerable divergence at elevated temperatures. At these temperatures (to 390° F.), the frictional behavior of the matrix alloy is intermediate between that of the bearing alloy and pure tin. Perhaps hard acicular crystallites play a more important part in determining the basic frictional properties of this alloy.

It is interesting to compare the lead-base and the *(Cont. on p. 608)*

Table I — Coefficient of Friction for Lead Alloys

	Steel on Lead		Lead on Steel	
	Bearing Alloy	Matrix Alloy	Bearing Alloy	Matrix Alloy
Clean				
First run	0.4 to 0.45	0.4	0.55	0.7
20th run	0.7	0.8	0.75	1.1
100th run			1.0	1.2
Lubricated with mineral oil				
First run	0.12	0.14	0.32	0.35
100th run	0.11 to 0.12	0.17		
Lubricated with stearic acid				
First run	0.08	0.06 to 0.09		
Wear for 3000-cm. track (clean)	11 mg.	14 mg.		

Table II — Coefficient of Friction for Tin Alloys

	Steel on Tin		Tin on Steel	
	Bearing Alloy	Matrix Alloy	Bearing Alloy	Matrix Alloy
Clean				
First run	0.7 to 0.8	0.7 to 0.8	0.7	0.8
20th run	0.65 to 0.8	0.85	0.8	0.85
100th run			0.6+	1.0+
Lubricated with mineral oil				
First run	0.13	0.13		
100th run	0.1	0.12		
Wear for 3000-cm. track (clean)			0.2	>0.3

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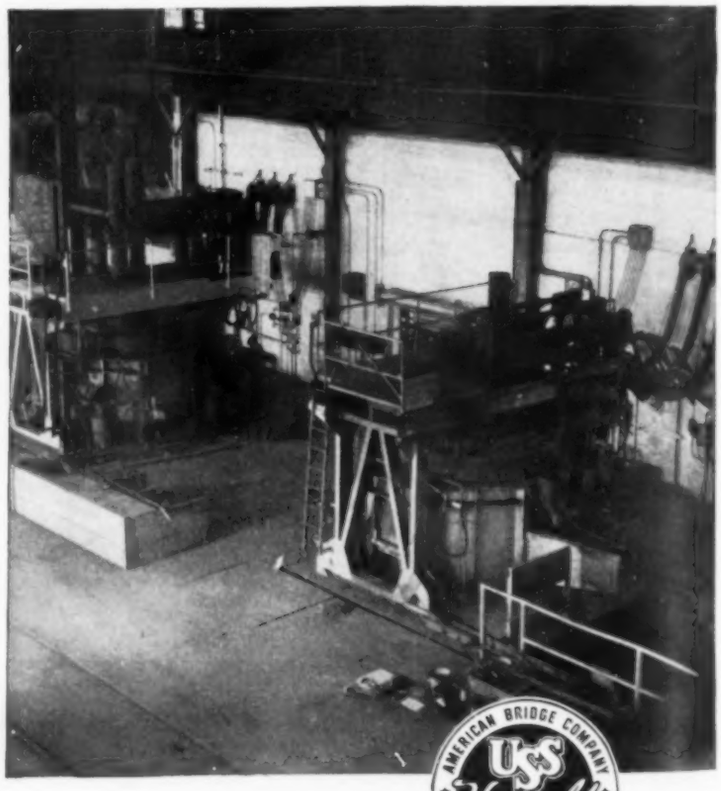

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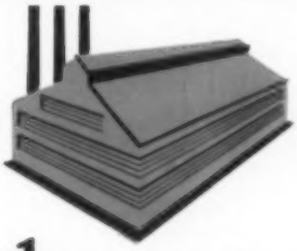
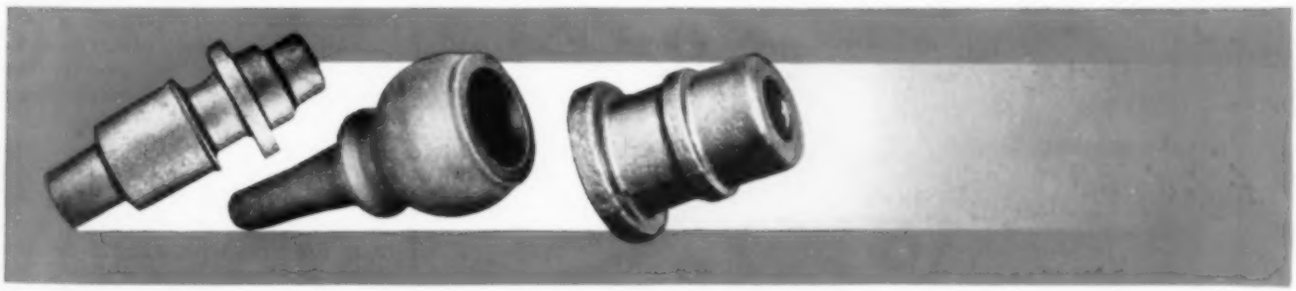
For **BETTER SERVICE** in **BETTER FORGINGS** ..deal with the ideally located organization that handles the entire job under  one roof and is directly responsible for all of it.



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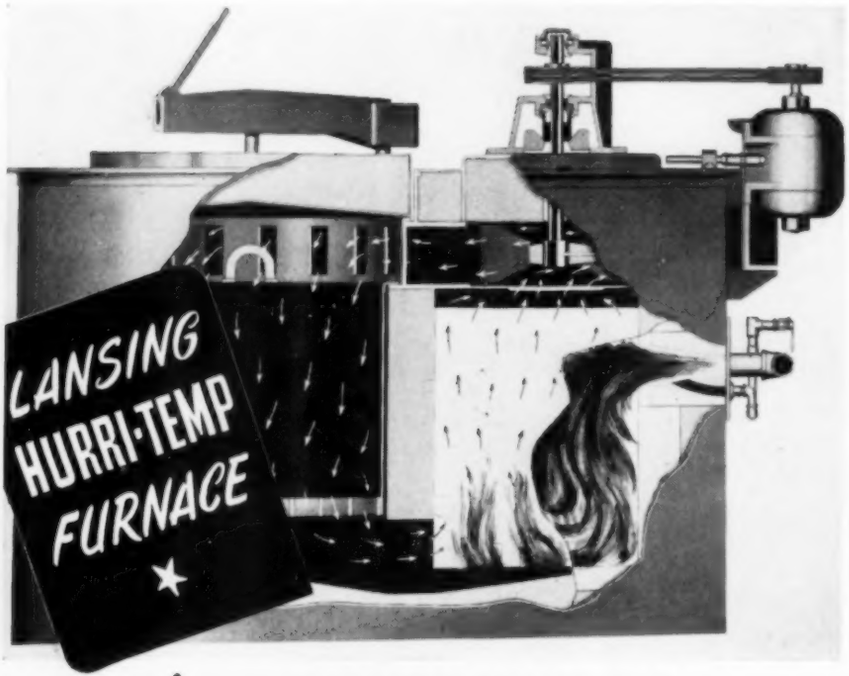

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Bearing Alloys

(Cont. from p. 606) tin-base alloys in view of the present shortage of tin. The frictional properties of the lead-base bearing alloy, clean and lubricated, at room temperature and at elevated temperatures, are generally slightly better than those of the tin-base bearing alloy. However, its wear on steel surfaces is very much heavier. Its hardness also is about 15% less. Apart from the question of mechanical properties, which may play a vital role in practical service, the lead-base bearing alloys should in practice be at least as satisfactory as the tin-base alloys from the viewpoint of friction.

Cracks in Thin Welded Plate*

THE RAPID PROPAGATION of cracks in relatively thin welded plates has been a matter for some concern. Static tests of cracked plates usually have indicated sufficient ductility so the material could not be classified as fundamentally brittle under either the uniaxial or biaxial stresses to be expected in thin plate. Since tests on notched bars have shown that the most ductile steel will be brittle under equal triaxial tensions, it is evident that triaxial stress may be involved in the propagation of cracks. If such a tension does occur and is the cause of the progressive failure, it must apparently be developed by the mechanism of the fracture itself.

All wide steel plates operate under a system of non-uniform biaxial stresses. If a crack is produced in a thin plate of normally ductile steel loaded at room temperature, the first inch or two of crack will be found to be a slipping shear fracture. Thereafter the crack may progress with a brittle herringbone fracture. This change in the character of the fracture is explained as follows:

After the ductile failure starts, the stress in the vertical direction can no longer be carried by this strip of plate but must be shifted to adjacent strips. One small section of the crack will therefore have a vertical stress of zero which would permit a thickening of the plate (Poisson's ratio effect). In the adjacent section, a great

(Continued on page 610)

*Abstracted from "How Does Propagation of a Small Crack Take Place in Thin Plates?" by L. E. Grinter, *Welding Journal*, June 1945, pp. 319s-320s.

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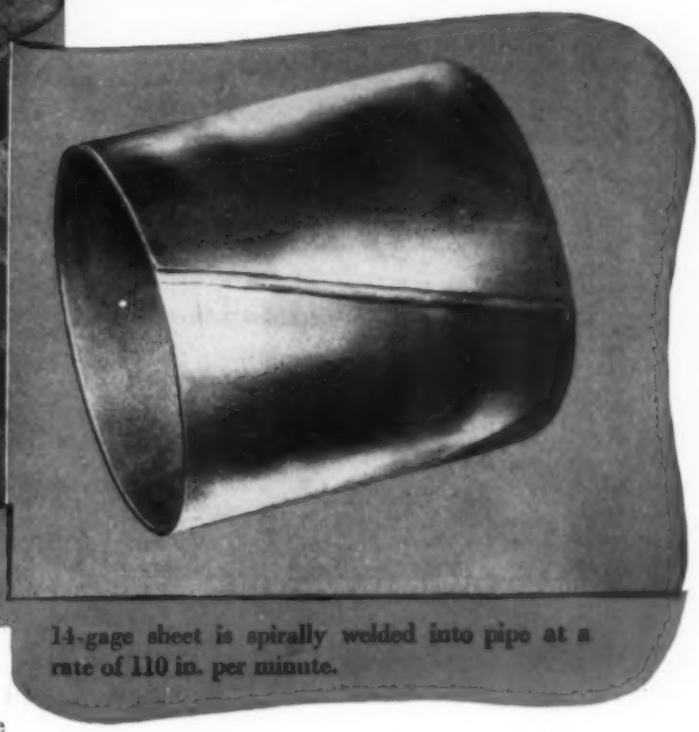

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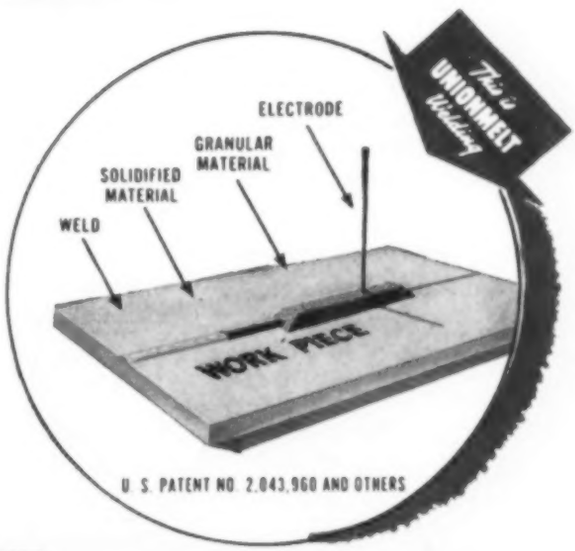

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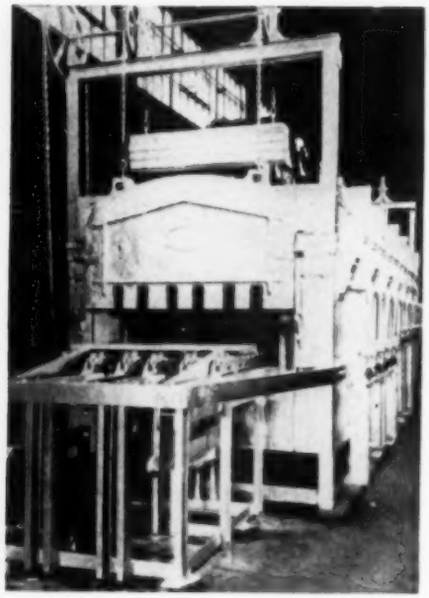

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Cracks in Thin Welded Plate

(Continued from page 608)

increase in the vertical stress will tend to reduce the thickness of the plate.

The result will be that the first section is thrown into compression and the second into tension normal to the plate so a triaxial tension of some magnitude appears certain to exist near the end of the crack. An estimate of 10,000 psi. for the third triaxial tension near the end of the crack is reasonable and probably conservative. At any rate, it is probably high enough to explain the change from ductile to brittle fracture.

The characteristic herringbone pattern is explained by the fact that the tension normal to the plate is zero at the surface and reaches a maximum at mid-depth. The biaxial stresses well ahead of the crack at the surface would appear to be high enough to give a shearing fracture if allowed time. At mid-depth, only the high stress concentration near the end of the crack would be adequate, along with the third directional tension, to give a cohesive fracture.

The wholly brittle fracture is also important. If the combination of high stresses, low temperatures and section change is sufficient to start a brittle fracture, the present theory explains how this fracture may propagate through areas of lower stress in a brittle manner.

Hardness Testing Errors*

AN AUTOMATIC MACHINE was developed for the non-destructive testing of small pieces of the same size and composition at the rate of 120 pieces per min. Each sample was magnetized to saturation and the retentivity measured by a search coil at the center of a solenoid with a field opposed to the original magnetization. The retentivity was taken as a measure of magnetic hardness. Diamond pyramid hardness tests were made on a few samples from each lot of pieces of equal magnetic hardness to obtain a correlation between the magnetic and the diamond pyramid hardness. However, it was found

(Continued on page 612)

*Abstracted from "Sources of Error in Diamond Pyramid Hardness Measurements on Hardened Steel", by W. N. Hindley, British Iron and Steel Institute Advance Copy, Sept. 1945, 10 pp.

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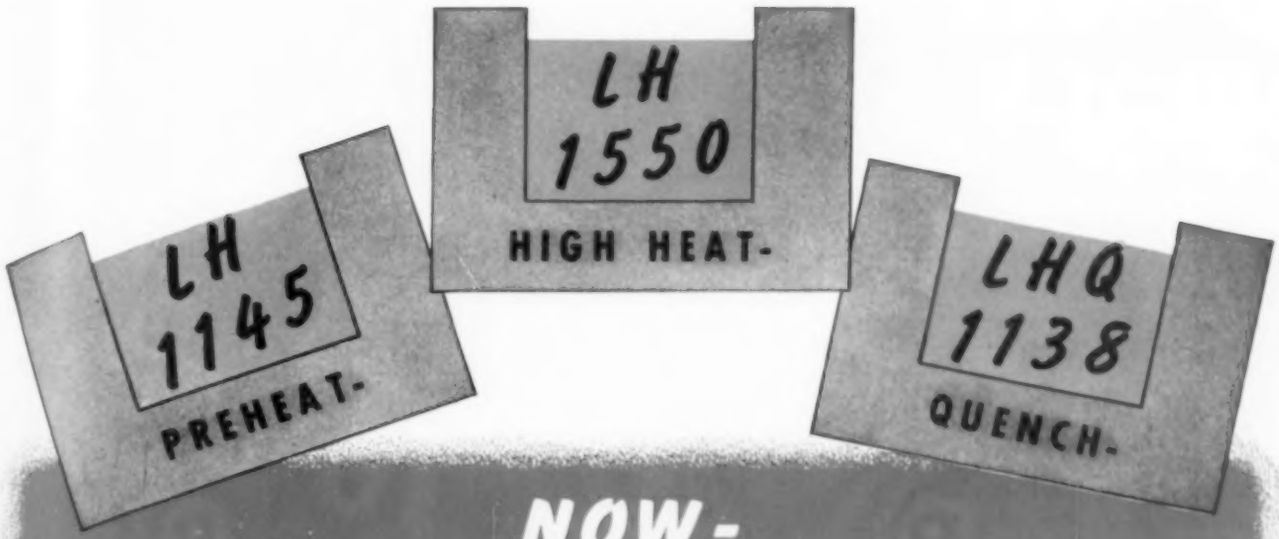

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Hardness Testing Errors

(Continued from page 610)

that widely different diamond pyramid hardness values were reported by independent observers on material of the same nominal composition and treatment, so an investigation of the error in this test was made.

Samples from two lots of steel were tested by 29 observers. Their readings were re-measured by another observer. Then all samples were re-tested by a single observer. Average hardness and probable error limits in the following table are based on results of a skilled observer who ground and polished new flats by the method recommended below.

Hardness	Lot A	Lot B
Diamond pyramid — average	870	790
Probable error limits	± 7.5	± 15
Lowest reading reported	505	540
Highest reading reported	950	940
Magnetic hardness	101 ± 1	90 ± 2

Variations in hardness readings were attributed to insufficient care in the preparation of the flats, use of a cracked or chipped diamond, or incorrect mounting of the specimen. Abnormally high readings by two observers were due to damaged diamonds on the hardness tester. The fracture in the diamond was of such a character as to offer greater resistance to penetration, thus giving a smaller impression and a higher hardness reading.

There was a greater tendency to obtain abnormally low rather than unusually high readings, due probably to the susceptibility of the hardened steel to local tempering during the grinding of the flat.

In many tests, the significance of the difference between the observers' readings and the re-measured readings was masked entirely by differences in the microscopic magnification. Therefore no assessment could be made of the error in setting the ocular knife-edges.

Since the accuracy and consistency of the impressions made by the machine depend mainly on the proper preparation of the flat, a standard surface preparation procedure has since been adopted. The rod is clamped in a vise and a carborundum file is applied with light hand pressure to give a flat about 0.1 in. wide. The specimen is then clamped in a jig and polished with five grades of emery paper ending with No. 00.

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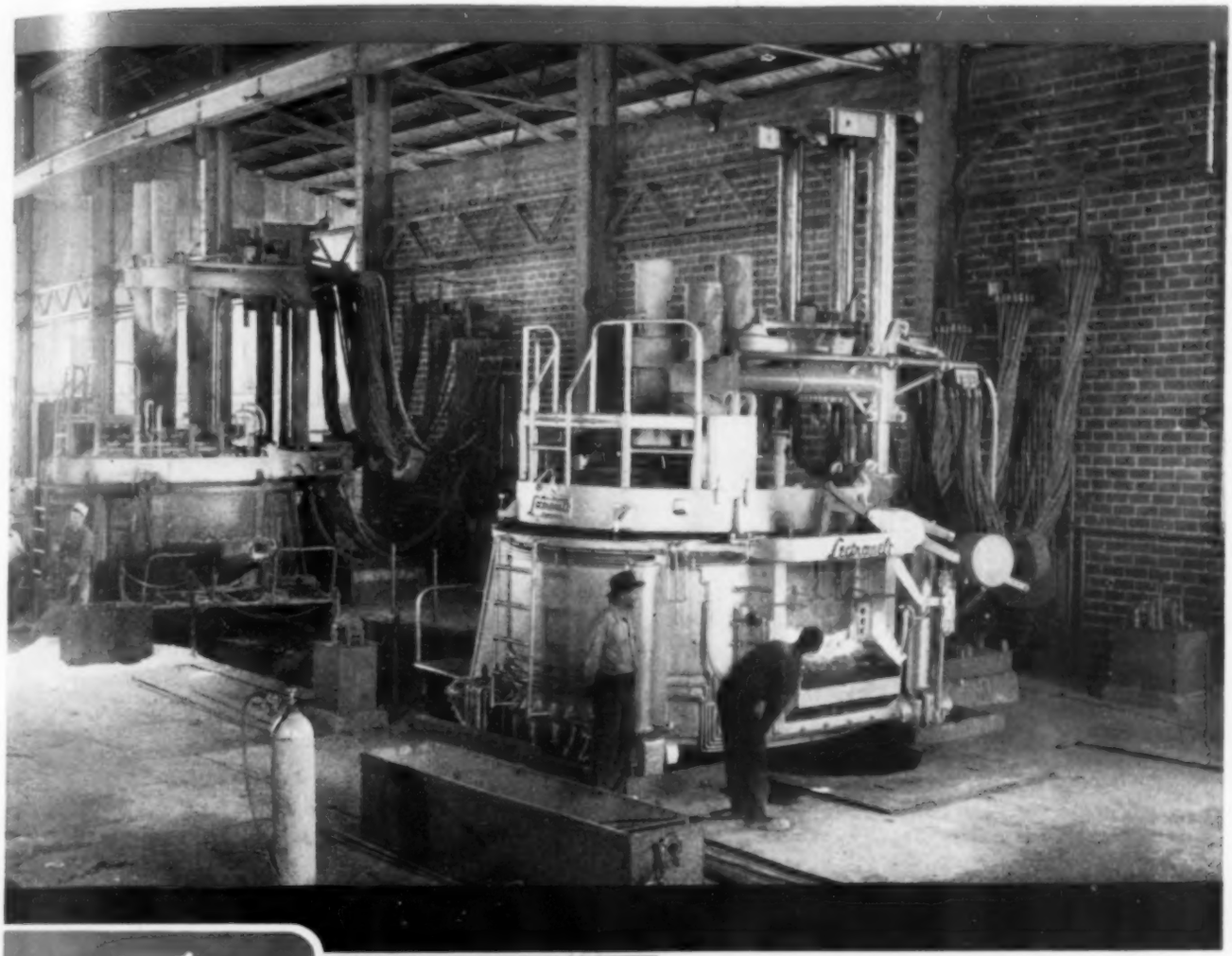

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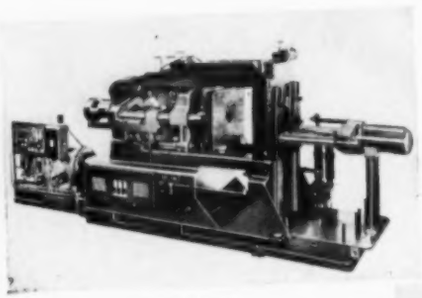
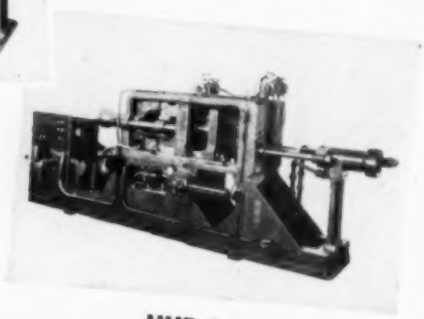
DIECASTING DIGEST

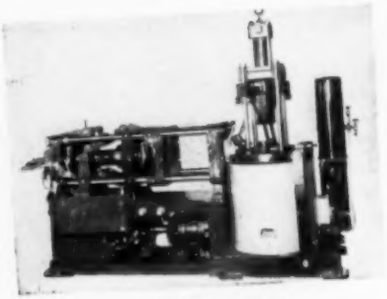
XI—Selecting the Machine to Suit the Job.



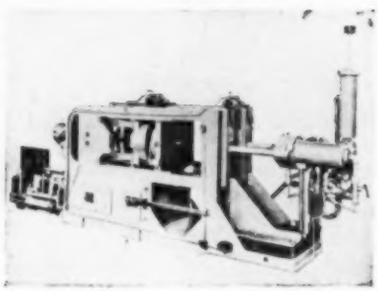
HHP-3-X



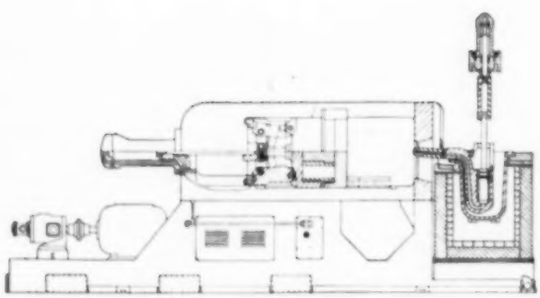
HHP-1-CC



HHP-2 (7.5)



HP-3½-X-SF



HP-2-SF

A very important factor in die casting is selecting equipment correctly rated for the job. To try to make castings which are too large or too heavy for the injection capacity and the die locking pressure of the machine employed, is a serious error. Such procedure can result only in imperfect castings, with high porosity and poor dimensional accuracy. The purchase of a machine too large for the production of small castings, is equally impractical, unless such castings are required in sufficient quantities to use large multiple cavity dies, advantageously.

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NORTON REFRACTORIES

Grinding Aircraft Gears*

DURING RECENT YEARS there has been an increasing demand for precision service gears. Some engineers feel that the grinding of hardened gears introduces a hazard and have therefore eliminated grinding on some lightly loaded gears. However, most gear grinding troubles can be traced to faulty or inaccurate operations prior to grinding. Gears are usually produced by shaping, planing, hobbing or milling. The machining must be accurate. The final grinding operation should not be relied upon to correct relatively large dimensional inaccuracies and errors. Many difficulties erroneously attributed to grinding would cease if the dimensional accuracy of blanks to be ground after heat treatment were controlled as accurately as it is for shaved gears.

Distortion during heat treatment depends on chemical analysis, method of heat treatment, design and proper machining of the blank.

*Abstracted from "Should Aircraft Engine Gears Be Ground?" by E. A. Koether, *Grits and Grinds*, v. 36, no. 8, August 1945, pp. 1-5.

The greatest objection to shaved aircraft engine gears has been the probability of distortion and decarburization in heat treatment. If heat treating could be improved to give more uniform distortion, shaved gears would replace ground gears to some extent, especially for lightly loaded gears. If the total error can be held to 0.0005 in. or less with practically no decarburization, grinding of gears may be substantially curtailed.

Gears are generally carburized to 0.030 to 0.040 in. with an allowance of 0.015 to 0.020 in. on the diameter for finish grinding. Some gears are machined as usual, then shaved before carburizing with only 0.006 to 0.007 in. allowance on the diameter for finish grinding. The decarburized surface must be entirely removed after heat treatment by blast cleaning to prevent burning of the tooth on grinding. Many gears are given an additional hot oil treatment at 350° F. before or immediately after the final grinding to relieve stresses due to hardening or previous rough grinding. Cracking is also minimized by avoiding excessive stock removal in the bottom of the tooth roots by grinding.

The proper selection of the grinding wheel is very important, as hard wheels hold their edge better than soft wheels and give a finer surface finish but have a tendency to burn the gear teeth and cause minute surface cracks. Cracks due to burning in grinding are generally found near the roots but seldom in the root bottom. Cracking which takes place in quenching usually occurs at sharp corners, holes or very thin cross sections. Very heavily loaded gears are now being ground to 30 to 45 micro-in. root mean square values to insure ample lubrication and to prevent the plastic flow of material caused by high momentary temperatures in service. Lightly loaded aircraft gears may be produced with much finer surface finishes.

The actual gear tooth loads are not steady but are intermittent. Extreme accuracy of the gears has little effect at very low or very high speeds, but is a most important factor at intermediate speeds. Greater dynamic loads can be carried on accurately ground gears than on those finished by shaving which does not provide for correction of tooth contour inaccuracies after hardening. *(Cont. on p. 656)*

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Grinding Aircraft Gears

(Continued from page 654)

Although the accuracy of all manufacturing operations of hardened aircraft gears is important, interchangeability and precision with maximum resistance to the intensities of the various tooth loads can only be achieved by final grinding.

Carburizing Practice in Germany

THE FUNDAMENTAL theory of surface carburizing has been discussed in a fairly detailed manner by L. Kolar and K. Juethner.* In German practice, surface hardening by carburization involves a number of treatments and always at least two — namely, carburization and subsequent hardening treatments. The depth of the carburized skin is governed by the shape and dimensions of the part; in German practice, as a rule, the depth varies between 0.015 and 0.06 in. The transition zone between carburized case and soft core should be as generous as possible. The structure desired for the hardened carburized case is homogeneous martensite, sometimes with small, uniformly distributed carbides of hyper-eutectoid cementite; the amount of carbides that is desirable or permissible depends on whether the service requirements are for strength or wear resistance.

Carburizing technique for casehardening has been discussed at considerable length by V. P. Sacchi.** This Italian engineer believes that hardened case carburized layers should show the following characteristics: Any marked separation of structural constituents of a hyper-eutectoid nature is undesirable since these tend to increase brittleness and lead to flaking away of the hardened case. Free cementite should also be absent; separation of crystalline cementite is believed to reduce intercrystalline cohesion and increase brittleness, and needle-shaped cementite accentuates this effect. Large needles of martensite are likewise undesirable. Overheating during the hardening treatment leads to grain growth, and to extremely minute intercrystalline fissures.

Mr. Sacchi notes that, in spite of the voluminous references in the technical literature, the precise mechanism of the carburizing reaction has not yet been satisfactorily explained. The assumption that casehardening by a solid agent is effected by the slow penetration of solid carbon from the hardening medium into the steel core was shown to be fallacious by F. Giolitti when he demonstrated that a part, completely surrounded with pure carbon and heated in a vacuum — namely, under conditions involving the total exclusion of all gaseous constituents — absorbed no carbon at all. It is now accepted that the casehardening process is governed only to a small extent by elementary carbon and is effected principally by the action of gaseous compounds, particularly carbon monoxide. Casehardening media having combined nitrogen, especially cyanide or ammonia compounds, presumably cause two hardening reactions to proceed simultaneously — namely carbon and nitrogen ab- *(Cont. on p. 658)*

Korrosion und Metallschutz, v. 19, no. 12, December 1943, p. 309.

**Korrosion und Metallschutz*, v. 19, no. 12, December 1943, pp. 312-319.

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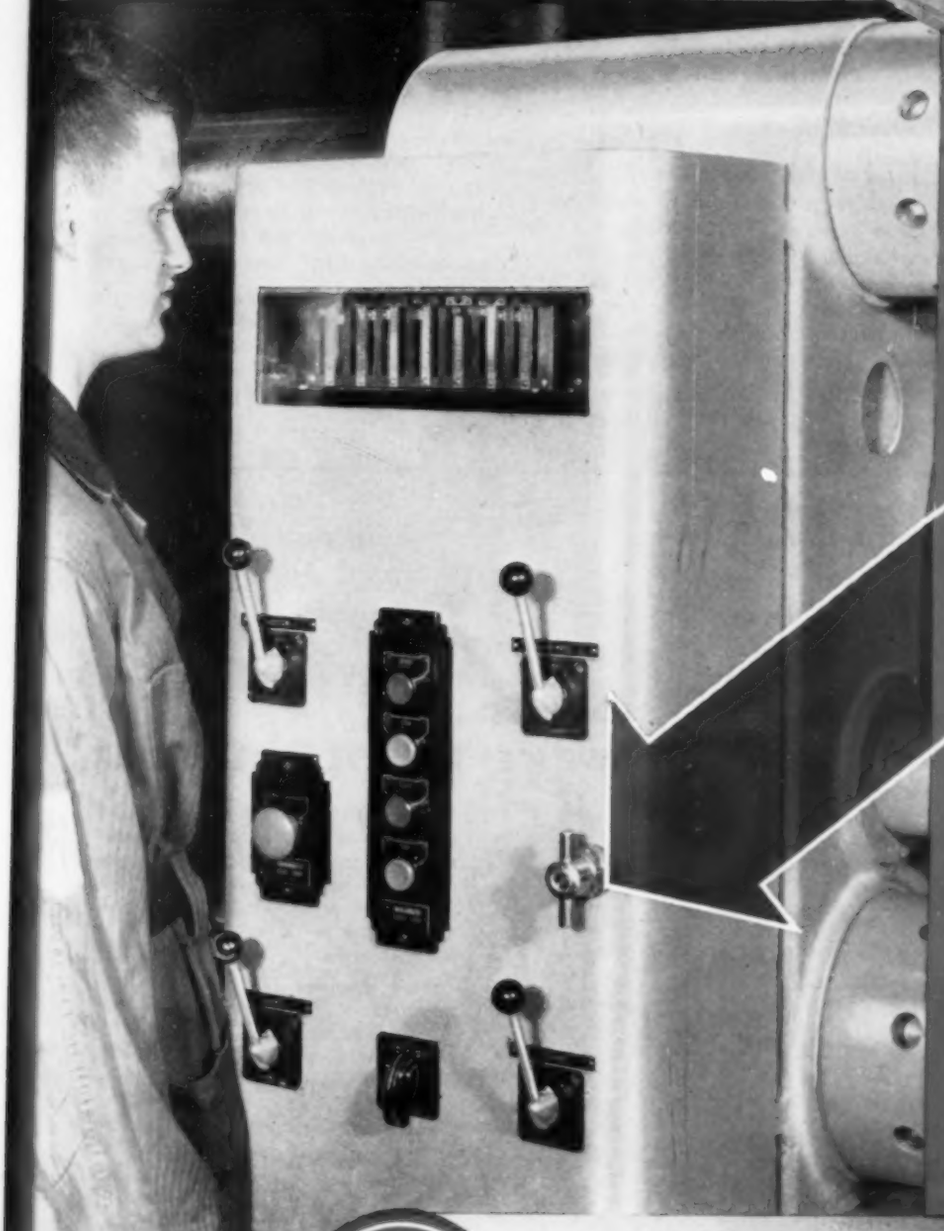

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(*Cont. from p. 656*) sorption. Since case carburization is fundamentally based upon gaseous reactions, the most suitable casehardening medium will be one in which the decomposition velocity of the gaseous compounds formed is lower than the velocity of diffusion of the carbon. If this were not true, the distribution of the carbon would be non-uniform and elementary carbon or sooty carbon compounds would accumulate on the surface.

In Italian practice on small parts, the carbon content of the steel should be about 0.12%, for medium sized parts about 0.15% and for large parts about 0.20%. Casehardening is done at 1650 to 1750° F. Special steels are usually used for the automotive and aircraft industries, because of the continually more stringent requirements imposed. The additional alloying elements have a large influence on the treatment and working conditions. Mr. Sacchi reports that those alloying constituents which form solid solutions with gamma iron and which remain in solid solution after slow cooling, generally slow up the carburizing process; thus for a given temperature and depth, a lesser depth of case is obtained. Manganese has been substituted for nickel in Cr-Ni steels and Cr-Ni-Mo steels. Casehardening compounds prepared in the form of a paste are being increasingly used in Italy.

Liquid casehardening baths are discussed by A. Kozelli★ who prefers liquid carburizing and nitriding baths because of their simple handling and rapidity of working. Nitriding has proved a popular treatment for small tools of high speed steels (or rather cyaniding, to differentiate from normal nitriding in ammonia gas). The high speed tool is ground to fine tolerance before treatment; after cyaniding, no further grinding is necessary. The usual period of time is from 1 to 2 hr. A high tungsten toolsteel (18%) takes less time than one with a lower tungsten content (2.7%). It is not particularly important to get any great depth of case when cyaniding a high speed toolsteel; of far greater importance is to have as high a surface hardness as possible. A remarkable fact is the extraordinarily high hardness obtained on cyaniding the substitute 2.7% tungsten steel — 1480 Vickers.

★*Korrosion und Metallschutz*, v. 19, no. 12, December 1943, pp. 320-322.

Microporosity★

MICROPOROSITY TESTS were made on alloys with up to 12% aluminum and 6.5% zinc. Melting and casting technique was such as to insure the absence of significant amounts of microporosity which might arise from the presence of gas. The investigation was confined to the type of microporosity most important in practice, namely, that caused by local loss, by feeding, of the eutectic liquid. The alloys were examined for "inherent" tendencies to microporosity as demonstrated by mechanical properties and radiographic examination of an arbitrary, sand cast, flat plate test casting. Only the tensile strength and elongation (*Cont. on p. 660*)

★Abstracted from "The Properties of Some Magnesium-Aluminium-Zinc Casting Alloys and the Incidence of Microporosity", by F. A. Fox. *Journal of the Institute of Metals*, v. 71, 1945, pp. 415-439.

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Microporosity

(Cont. from p. 658) were determined in the mechanical property tests since these were found to be most sensitive to microporosity.

As judged under these conditions, the sand cast magnesium-aluminum-zinc alloys had different inherent tendencies to microporosity. The influence of zinc was generally adverse. Better results were obtained in the low zinc alloys when the aluminum was over 8%. The alloy with 6.5% aluminum and 3% zinc was among the worst, while an alloy with the same zinc content but higher aluminum was less undesirable. However, an alloy with 9% Al and 2% Zn was less susceptible to microporosity than an alloy with 0.5% Zn.

Radiographically visible microporosity resulted in average tensile strength values 5 to 30% lower than those obtained on similar material relatively free from microporosity. The maximum tensile strength normally encountered in alloys with about 5% aluminum was displaced when microporosity was present to alloys with about 2.5% aluminum. The elongation also suffered from the presence of microporosity. Nevertheless, all alloys were not affected by microporosity to the same extent. Some alloys with very severe tendencies to microporosity showed only about the same reduction in strength as alloys less prone to microporosity. The 6% aluminum 3% zinc type, no longer used in England because of its tendency toward microporosity, was more likely when microporous to be deficient in pressure soundness and in some dynamic properties than in its static properties.

Corrosion of Magnesium Alloys*

CORROSION TESTS were made on samples of Elektron A 8 (8% aluminum, 0.5% zinc, 0.25% manganese and under 0.0022% nickel) with varying iron contents from 0.001 to 0.025%. The specimens were machined from ingots and were tested in three conditions—as cast, solution treated for 24 hr. at 790° F., and fully heat treated by a solution treatment followed by 18 hr. at 390° F. The corrosion resistance was tested by atmospheric exposure and by immersion in a 3% sodium chloride solution with a pH of 10.2 at 70° F.

There were no systematic variations in corrosion resistance which could be attributed to the varying iron content. It can therefore be concluded that in alloys of this type with 0.2 to 0.3% manganese, in all states of heat treatment, the corrosion resistance in atmospheric or total immersion tests is independent of the iron content even down to very low iron contents.

It was found that material in the solution treated condition corroded faster than in the other conditions when tested by the immersion test, irrespective of the iron content. However, this difference in corrosion resistance was largely absent in the atmospheric tests. The reason for the discrepancy in the results of the two types of corrosion tests presents a fundamental problem which is being investigated further.

*Abstracted from "Further Observations on the Protective Influence of Manganese in the Corrosion of Aluminium-Containing Magnesium Alloys", by F. A. Fox and C. J. Bushrod. *Journal of the Institute of Metals*, v. 71, May 1945, pp. 255-265.

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